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Edited for the Council by W. BARNARD FARADAY, LL.B., F.S.S., Barrister-at-Law

All communications should be addressed to the Editor.

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Notices of the Royal Aëronautical Society.

The Patron.

We have the honour to announce that H.R.H. the Prince of Wales has been graciously pleased to signify that he will act as Patron of the Society.

The Chairman.

At a meeting of the Council held on July 15th, Brigadier-General R. K. Bagnall Wild, C.M.G., R.E., was unanimously elected Chairman of the Society for the ensuing year.

The Glasgow Branch.

A branch of the Society has been formed at Glasgow. Sir William Beardmore has consented to act as Chairman of the branch, with Mr. J. Buyers Black as local Hon. Secretary. The offices of the branch are at 4, Jane Street, Blythswood Square, Glasgow.

Elections.

The following have been elected members of the Society in the various grades:—

Students.—Thomas Hampson, Robert Wright.

Associate Members.—Captain N. Grabonsky Atherstone, Captain John Barron, Lieutenant J. S. Bellis, Lieutenant J. S. Bradley, Lieutenant W. Catchpole, Captain W. J. Coombes, Second Lieutenant Reginald S. Corbett, Second Lieutenant R. H. Foxlee, Second Lieutenant H. Neville Hasler, Captain W. Charles Titheradge, Captain R. H. Wann, Robert Lloyd Woolcombe, M.A., LL.D.

Members.—Colonel Roland C. S. Hunt, Captain Herbert Carmichael Frewen, Corporal Angus Maccoll, Second Lieutenant Ian M. Perman, Robert Henry Thomas Wil-de-gose.

The Syllabus.

It is very desirable that members desiring to offer lectures or papers to the Society during the ensuing session should do so at the earliest possible date, so that adequate arrangements may be made and suitable consideration given to the

papers. In submitting papers members are urgently requested to send them in with all illustrations and diagrams in a suitable form for reproduction. Blue prints can under no circumstances be accepted. It is further pointed out to members that it is desirable in the interests of full discussions that prints of papers should be circulated before each meeting. This can only be done if members will follow the suggestions given above. The Syllabus for 1919-20 is now under consideration.

The Garden Party.

A Garden Party in celebration of the conclusion of Peace, of the 53 years' life of the Society and of the fact that the Society now exceeds 1,000 members, was held on Sunday, June 29th. Messrs. Handley Page, Ltd., very kindly lent their aerodrome for the occasion, and offered every facility for the holding of the gathering; the spacious works, which were thrown open to the guests, forming one of the most attractive of the interests displayed. The thanks of the Society are due to Messrs. Handley Page, Ltd., in the first place; to Major L. N. G. Filon, F.R.S., and Commander Baker for their lecture on transatlantic navigation; to Major A. H. Wood, D.S.O., and the Department of Aircraft Production Concert Quartette; to the Royal Air Force Band; to Messrs. E. R. Calthrop's Aerial Patents, Ltd., for a parachute display; to Mr. Chas Solby for his flying models, and to Brigadier-General Brooke Popham and his assistants for the exhibition of apparatus prepared by the Technical Department. A special word of thanks is due to those members of Messrs. Handley Page's staff who acted as stewards. It was impossible for these duties to have been better carried out. Mr. E. Cogin (Messrs. Handley Page, Ltd.) took great trouble with the arrangements, and the success of the gathering is very largely due to his efforts. It is perhaps sufficient to say that a large number of members and their guests (some 1,200 in all) were constantly interested and amused throughout the afternoon, and that the hope has been expressed that a similar gathering may be held annually.

"LIGHTER-THAN-AIR CRAFT."

BY LIEUT.-COLONEL T. R. CAVE-BROWNE-CAVE.

SUMMARY.

Factors Governing the Variation of Lift of an Airship.—Distribution of Weight and Rigidity of Envelope, Rigid, Semi-Rigid and Non-Rigid, Parseval and Astra.—Hull Structure of Rigids.—Sub-Division of Gas Space in Large Ships.—Attachment of Riggings to Fabric.—Blowers.—Airship Valves.—Bow Stiffening for High Speed.—Stabilising Planes.—Airship Fabrics.—Airship Engine Requirements.—Factors Governing Useful Carrying Capacity.—Water Recovery and Use of Hydrogen as Fuel.—Types of Airships Developed During the War.—Airship Handling, Mooring, Towing and Anchoring.

Since I was asked in September last to read this lecture conditions have so changed that it has been necessary totally to re-cast and re-write what I then proposed to say. A large amount of information as to the actual achievements of airships has been published and also perhaps an even larger amount of speculation as to their future possibilities. What will, therefore, probably be of interest to a technical society such as this is a general outline of the ships as they exist at the stage to which they have been developed during the war.

In order to make clear the various matters which influence the lift and behaviour of an airship, I have introduced a small amount of aerostatics which will appear obvious and unnecessary to many, but may help others to the understanding of the more interesting points treated later.

The extent of the detail which I have been allowed to include in the lecture, although such matters have not been published before, leaves the Society with a very deep debt of gratitude to the Admiralty.

Factors Governing the Variations of Lift of an Airship.

An airship derives her lift from the difference between the weight of the structure and all parts of the airship and the upward force on the airship, which is equal to the air which she displaces. The majority of this displacement is that due to the part of the ship which is filled with gas.

The variation in lift of the ship will therefore depend primarily upon the volume of gas in her envelope and upon the density of the surrounding air.

As the ship increases her height from the ground the density of the surrounding air decreases, and owing to the decrease of pressure the hydrogen contained in the gas space will expand at a corresponding rate so that, other things being equal, the available lift of the ship will remain the same. This process will continue until a height is reached at which the air has been totally expelled from the air chambers and further expansion of the gas necessarily results in the discharge of some gas from the relief valves in the envelope. Any further rise will, therefore, produce a decrease in the lifting power of the ship.

Alteration of atmospheric temperature is usually accompanied by a corresponding alteration of temperature of the gas, and providing the two temperatures remain the same, there will be no effect on the lift, so long as gas is not discharged from the envelope.

Variations in barometric pressure, *i.e.*, density of the atmosphere, affect both the density of the air and the density of the hydrogen, and a ship which is full

of gas will therefore have considerably greater lift on a day when the barometer is high. This indicates that the lift of a ship may be expected to be good during cold weather with a high barometer. Summarising this in symbols:—

$$\text{Lift} = V\,(Pa - Pn) \text{ where}$$

V = volume of gas space,
Pn = density of gas,
Pa = density of air displaced.

An important variation in lift is caused when the airship is exposed to the heat of the sun and the temperature of the gas inside the envelope becomes higher than the temperature of the surrounding air. The extent of this difference of temperature will vary with the strength of the sun and also with the rate at which the surface of the envelope is being cooled by the passage of air over it. This difference under certain circumstances may be very large and may vary rapidly. Instances have been recorded in which there has been a difference of over 30° F. between the gas and air temperatures. The gas temperature reckoned on the absolute scale was then some 6% higher than that of the atmosphere and a "false lift" of 6% of the total displacement of the ship was therefore produced.

The reduction of lift caused by rain falling on an airship is comparatively small provided the surface of the envelope is made waterproof. Snow will not in general stick to the surface of an envelope, but in the event of meeting snow sufficiently wet to stick to the surface, and possibly later to freeze on to it, considerable increase of weight might very rapidly be acquired. There has been considerable experience of ships meeting snow while in flight, and as far as is known no serious trouble has actually been experienced due to snow sticking to the surface of the envelope.

Distribution of Weight and Rigidity of Envelope.

The problem of suspending a weight from the lightest possible gas container is one which involves careful consideration of the ordinary principles used in calculating the distribution of loads and bending moment in ships and similar structures. The rigidity of the gas container may be provided in various ways. The simplest is to make it solely of a perfectly flexible fabric with no rigid stiffening whatever. Such an envelope is referred to as a non-rigid. It is kept distended to its correct shape by the internal pressure which is maintained slightly in excess of the pressure outside. Fabric may be regarded as capable of resisting tension and a considerable amount of shear, but it is, of course, incapable of resisting compression. A single concentrated load suspended below the envelope will tend to produce compression in the underside of the envelope, partly by reason of the inward pull of the riggings, some of which must necessarily be inclined from the vertical, and also by any bending moment due to any lack of uniformity of distribution of load over the length of the envelope. The internal gas pressure produces a longitudinal tension in the fabric. If the compression due to the riggings exceeds the tension due to the internal pressure the envelope will deform.

An alternative method of maintaining the shape of the gas container is to form the hull of the ship as a rigid structure of sufficient stiffness to maintain its own shape independent of any internal gas pressure. The forces tending to deform this structure will depend upon the distribution of loads and upon the distribution of gas inside the hull. Ships constructed on this system are described as rigids.

Intermediate between these two main types there is one referred to as the semi-rigid. This class is provided with a rigid keel of sufficient strength to maintain its rigidity under the action of the various loads of the ship. The keel is carried by the envelope which contains the gas, but unlike the rigid the

envelope is dependent for its shape upon the excess of internal pressure. There is yet another type, one which is extensively used in Italian airship construction, in which the keel is not capable of taking a bending moment but is capable of taking longitudinal compression when held straight by the main envelope.

Of these various types of construction it may generally be said that for small ships the non-rigid arrangement is entirely satisfactory as the envelope is amply capable of providing sufficient rigidity with reasonably small internal pressure. For very large ships it becomes necessary to divide the gas chamber into a number of compartments for a reason which will be explained later, and also the large diameter would render the tension in fabric caused by the necessary excess of internal pressure very considerable. For this reason a rigid structure, which calls for no excess of internal pressure, will almost certainly have to be adopted for airships of the largest class. The semi-rigid is a type which has been practically undeveloped in this country. The Italians, however, have done a great deal of work on ships of this description, but it appears very doubtful whether, all other things being equal, there is much to be gained by the addition of a rigid keel to a non-rigid envelope. The keel of a semi-rigid ship has to be sufficiently strong to take the loads of the airship without the assistance of the envelope, because in the event of pressure in the envelope falling the keel would collapse, and the ship could not be restored to her correct shape by making good the pressure in the envelope. Non-rigids which have lost pressure have frequently buckled in the air to a seemingly alarming extent, but have continued their flight undamaged as soon as pressure has been restored. The Italian system of providing a keel capable of taking only longitudinal thrust is an extremely ingenious one, but it is not found in actual practice that very much advantage in overall height of the ship can be effected by this method. This, of course, is due to the fact that the points of attachment of the riggings are moved down from the level of the centre of the envelope to the level of the keel.

The design of the envelope of non-rigid ships is a matter which requires a very considerable amount of careful consideration.

The overall height is restricted by the size of the airship shed and also by the power of the elevators which are required to incline an airship of which the car is far below the centre of the envelope. If the weight is concentrated and placed close to the envelope the riggings necessarily lie at a very flat angle and exert a serious longitudinal compression. This has to be resisted by a high internal pressure, which in turn causes great circumferential tension and involves the use of correspondingly heavier fabric for the envelope. The general consideration of the rigidity of an envelope is one of very considerable complexity, and may be most conveniently tackled by arranging a model experiment in which the lift of the gas and the distribution of load is reproduced in a small envelope filled with water and inverted, the weight of the water acting downwards corresponding with the lift of the gas acting upwards in the full size ship. The load is taken by a number of wires arranged similarly to the riggings and passing over pulleys which support the equivalent of the load of the airship. The weight of the planes and other envelope fittings can similarly be represented. Pressure in the envelope is maintained through a tube connected to a water reservoir, the level of which can be varied. A convenient method of determining the pressure in the water model, which shall correspond to similar pressure in the airship, can be obtained as follows:—The pressure in an airship could be maintained at any desired value by fitting an open-ended hose to the bottom of the airship and filling the airship with gas until gas issued from the lower end of the hose. If the end of the hose is at a distance of M metres below the bottom of the envelope the pressure of gas at the bottom of the envelope will, as explained later, be M millimetres of water above atmosphere. Similarly in the water model, the height of the free surface of water above the envelope corresponds to the internal pressure at that point, and as the dimensions of the model and the envelope have

been arranged correctly to scale, the comparison is a direct one. For example, if the diameter of the airship is 15 metres and it is desired to maintain a pressure of 20 mm. of water at the bottom of the envelope, the length of the open hose must be equal to 20 metres, *i.e.*, 20/15 of the diameter of the envelope. This is reproduced in the water model by maintaining the water surface at a distance above the envelope equal to 20/15 of one diameter.

The method of carrying out these experiments is a very simple one. The various loads are distributed along the envelope and the pressure is reduced until the fabric begins to pucker at some point. The value of this pressure is noted.

The distribution of load may then be varied in order to reduce the compression in the fabric at this point.

It is desirable to arrange the water model so that the whole system can be inclined up or down at one end in order to reproduce the conditions of the airship pitching. Provision against pitching occasions greater difficulty than the mere satisfactory suspension of the load when the ship is on an even keel. It is not possible to give any simple rules for arranging the rigging of the non-rigid ship, but one system which has been found generally satisfactory is to lead wires from points distributed along the envelope at intervals suitably proportioned to the lift of gas at each section. This provides for the suspension of the load on an even keel. Independent wires should then be provided to prevent "fore and aft" motion of the airship car when the ship becomes inclined. It will easily be seen that the tendency to deform the envelope very materially reduces as the distance of the load from the envelope is increased and also if the load can be divided into two or more separate units.

The point at which the riggings are attached to a circular envelope is necessarily some distance below the axis. If it is possible to raise the level of these points of suspension to a higher point on the envelope, the height of the ship can be correspondingly reduced.

Further, the direct longitudinal compression due to the riggings is applied at a point considerably above the axis of the ship, *i.e.*, at a point where the difference of pressure and therefore the longitudinal tension of the ship is greater than at the lower levels. This principle was satisfactorily achieved in the system invented by a Spaniard, Signor Torres Quevedo, and subsequently developed by the Astra Company of Paris.

The envelope is made of trilobe cross section and the riggings are led into the envelope at the bottom ridge and parted into two fans of strings secured to points along the top ridges.

To constrain the envelope to this trilobe shape, curtains of ordinary unproofed fabric are laced to the ridges. These do not, however, divide the ship into separate gas compartments.

The system adopted by the Parseval Company is to provide a strong rigging band as a kind of girdle on the lower part of the envelope. To this the car is attached. The shape of the envelope is maintained by reinforcing bands of webbing stuck to the surface of the envelope along trajectories, the position of which is determined by experiment.

Both these systems and also the semi-rigid design involve considerable complexities and are only rendered necessary in order to suspend a concentrated weight as close as possible to the envelope. If, however, it is not necessary that the weight should be concentrated and it is possible to distribute the majority of the weight in a number of separate cars or along the envelope itself, these systems and the complexities they involve can be abandoned.

Structure of Rigid Airships.

The framework of a rigid airship consists of a number of rigid longitudinals connected by a number of transverse members, which form rings at intervals

along the length of the ship. Each of these rings is braced in its own plane by a number of radial wires. The gas bags are placed in the compartments between these bulkheads of radial wires. The outer cover is stretched over the outside of the framework.

In order to transmit the upward pressure of the gas bags to the framework, nets are provided and attached to the inner edges of the various rigid members of the framework.

The weights carried by the ship are mostly placed in a strong keel, which runs along the bottom of the ship. The function of the keel is primarily to distribute the load of these weights to the main transverse sections of the ship. The cars which are suspended below the hull of the ship are also attached at points which bring the load on to the main transverse bulkheads. Special lift wires are arranged, in addition to the radial wires, to transmit the load of the keel to the upper part of the framework.

If, for any reason, one gas bag becomes much less inflated than those on either side of it, there will be considerable pressure tending to bulge the radial wires towards the empty bag. Tension in these wires may produce very serious compressive strain in the transverse members, and in order to assist in resisting the bulging action an axial wire is often led along the axis of the ship and secured to the wires of each bulkhead.

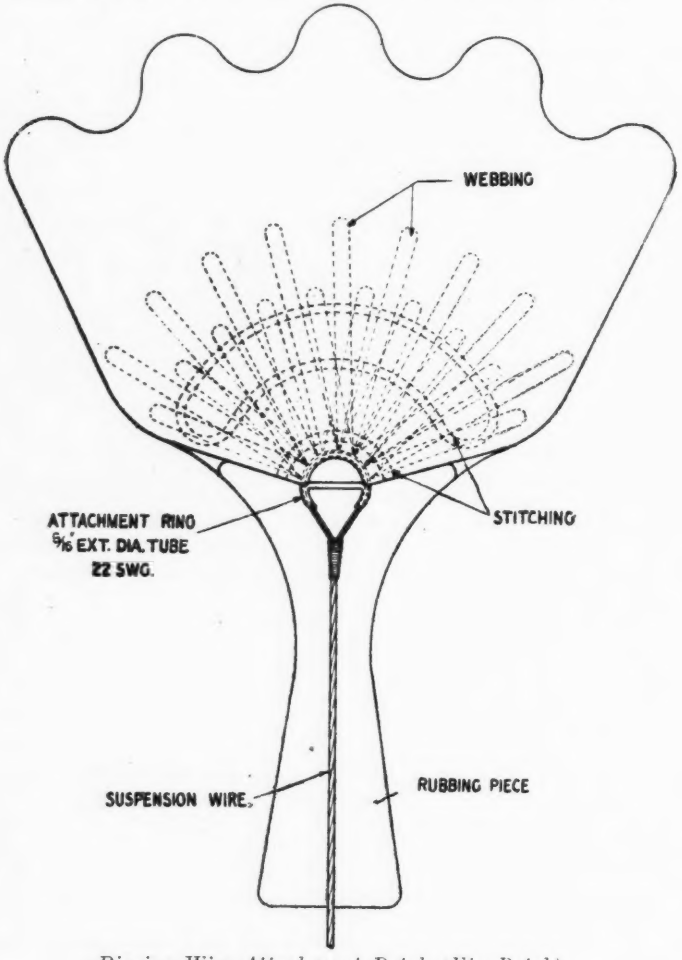
Sub-Division of Gas Space in Large Airships.

The necessity for dividing the gas space into a number of separate compartments is not primarily due to the possibility of losing the whole of the gas from one compartment by leakage from external damage to the fabric. As long as an airship remains on an even keel the pressure at the two ends of the ship will be approximately the same, but if the airship be now placed vertically head upwards the excess of the internal pressure at the top of the ship over that in the air outside will be considerably greater than that excess at the bottom of the ship. This is due to the difference in weight of a column of air and a column of hydrogen equal to the length of the ship. The same variation of internal pressure will obtain in a lesser degree when an airship in ordinary flight has one end raised considerably above the other. It is convenient to remember that this variation of the difference of pressure amounts to 1 mm. for each metre difference in level. In the case of a non-rigid, which has to maintain a minimum difference of pressure between the inside and outside of the fabric of 15 mm., the effect of having the bow of the ship raised considerably above the stern will produce a large increase of pressure difference in the bow and consequently an increase in tension of the fabric at that point. In a short ship this increase of pressure due to inclination of the ship is small, but in ships of great length the increase would be a serious one. For this reason it becomes necessary to divide a long ship into a number of compartments, but this is only effective if the bulkheads, which isolate one compartment from another, are capable of maintaining difference of pressure between their two sides. In a rigid airship which has a number of separate gas containers arranged inside its structure this division is effective. There is, therefore, no accumulation of pressure at the higher end of the ship. The radial wires which form the bulkheads between the gas bags are capable of withstanding a certain difference of pressure between the gas on the two sides of the bulkhead.

Sub-division of the gas space is also desirable in order to avoid the surging of gas from one end of the ship to the other. An airship partly filled with gas would, if not sub-divided, tend to be very unstable as the gas would tend to run to whichever end happened to be the higher. In a non-rigid ship this surging is satisfactorily avoided by sub-dividing the air space into a number of ballonets so that the air in each can only move a short distance forward or aft.

Attachment of Rigging Wires to Fabric.

As indicating the method by which a steel wire may be attached to fabric and communicate the load to the envelope, the diagram shows such a fitting used for the main rigging for small non-rigid airships. The wire is passed through a tubular D-piece, round the outside of which are laid strips of webbing.

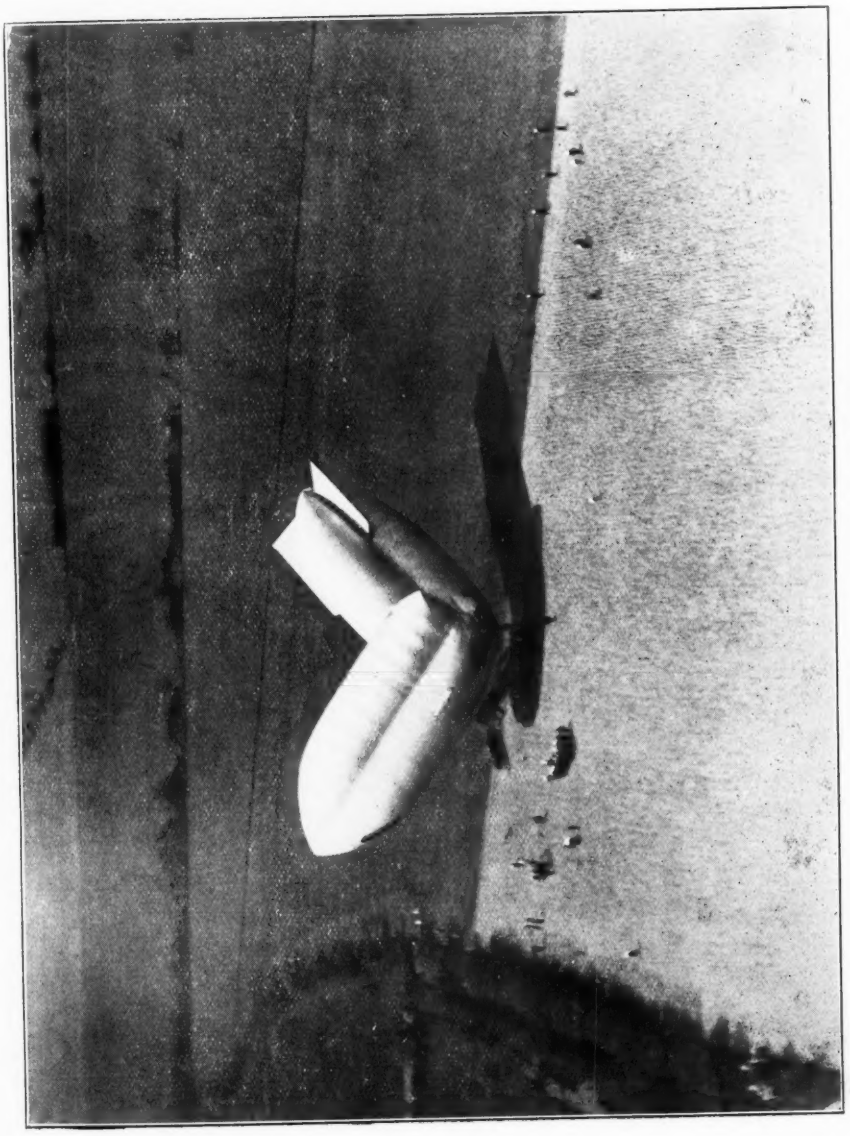


Rigging Wire Attachment Patch (Eta Patch).

These are stuck to fabric foundations which are extended over a small portion of the envelope. This construction serves satisfactorily to communicate the tension in the wire to the envelope and to give reasonably good distribution of stress.

Blowers.

In order to maintain the pressure in a non-rigid envelope, blowers of the ordinary low pressure rotary type were originally provided. These were driven

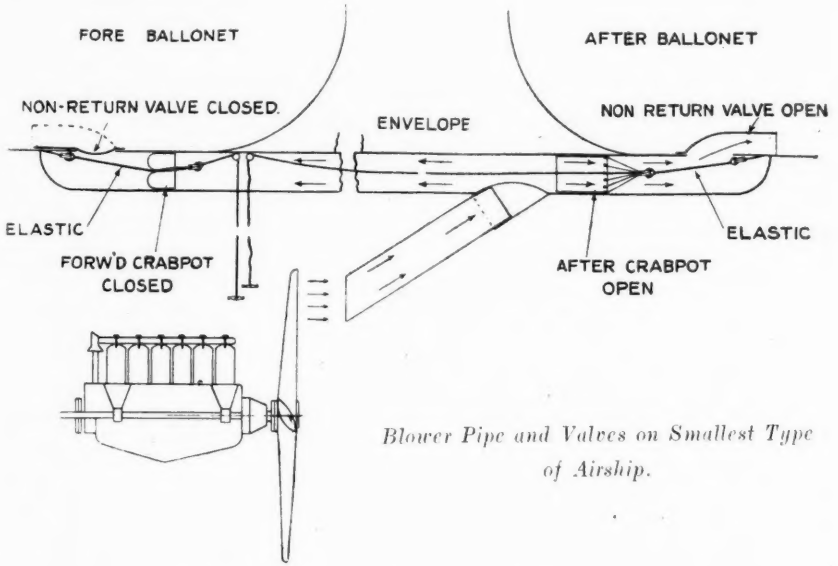


Coastal Airship during Temporary Loss of Pressure.

S.S. Airship in Mooring Out Ground in Wood.

either from the main engines or by separate small petrol engines. They occasioned, however, a very fruitful source of breakdown. It was subsequently found possible to replace them by what is termed a blower pipe, arranged to collect air from the slip-stream of the propeller and to discharge it into a duct which distributes it to the various ballonets of the ship. The energy required to provide this air at high pressure was derived at the expense of a slight increase in head resistance, and in order to avoid this, arrangements were made whereby the blower pipe could be hinged about its top end and folded up along the under surface of the envelope.

A method which is employed in Italian airships is to derive the pressure from the extreme bow of the envelope. The sufficiency of this pressure will be discussed later.



Blower Pipe and Valves on Smallest Type of Airship.

The distribution of this air to the various ballonets necessitates the use of shut-off and non-return valves. These were originally made from sheet aluminium and gave very considerable trouble. It was found, however, that fabric valves arranged in the form of a sleeve, which can be partially turned inside out, gave very effective results. This valve is referred to as a "crab-pot." It is very easily operated and is almost completely airtight. The diagram shows the arrangement of blower pipe and valves on the smallest type of ship.

To enable pressure to be maintained when the main engines are not in use an auxiliary blower is necessary. The rotary type of blower driven by a separate small engine was used for a considerable time, but proved capable of improvement both as regards space occupied, reliability and efficiency. A new type of blower was devised and consisted of a small specially designed propeller discharging into a shaped casing, shaped so as to avoid as far as possible all loss due to eddies. The shape of this orifice was very carefully determined and a large boss fairing was fitted to the propeller.

Careful tests made by measuring the h.p. and output of air showed that for the same h.p. and discharging against the same head the new blower would deliver three times the amount of air previously discharged by the rotary blower.

Airship Valves.

In order to prevent the pressure in the envelope exceeding a predetermined maximum and causing danger of bursting, valves are provided to relieve the pressure in the ballonets and in the gas space. The valves are made automatic in their action, and the gas valve is set to blow off at a pressure somewhat in excess of that adopted for the air valve, thereby ensuring that an increase of pressure is first corrected by discharging air from the ballonet valves. If this rate of discharge is insufficient the gas valve then lifts, but the discharge of gas is avoided wherever possible.

It will be realised that if these valves were constructed and spring loaded in the ordinary way, the pressure of the valve on its seating would be gradually reduced as the pressure inside the envelope increased. When blowing off point was nearly reached there would be a considerable period while the valve was only very lightly pressed on to its seating and when leakage was extremely likely to take place. The mechanism of the valve was, therefore, arranged so that the force tending to cause the valve to open decreased as the valve opened, and the result produced was, therefore, that the valve would remain on its seating until the predetermined pressure was reached. It then opened wide and would remain open until the pressure had fallen slightly below that at which the valve opened. This gives a very determined action and materially reduces the amount of leakage from a valve while it is "stuttering" in the very slightly open position.

The gas valves used for relieving pressure in a rigid airship are fitted in the lower part of the bag where they can be reached from the keel gangway. They are automatic, but are much larger and loaded to a much lower pressure. In addition to these relief valves, hand-operated manœuvring valves are fitted at the top of most of the bags so that gas can be released in order to alter the trim of the ship.

Bow Stiffening for High Speed.

The pressure which it is necessary to maintain in a non-rigid envelope depends upon two things:—Firstly, the pressure which is necessary to prevent the envelope from collapsing under the influence of the rigging tension; and secondly, the pressure which is necessary to prevent the bow of the envelope being blown in, due to the excess of external pressure caused round the bow of the envelope by the motion of the airship forward.

It is found that the excess of pressure which takes place at the bow of the ship extends for only a short distance aft. By reinforcing this area it is possible to fly with an envelope pressure considerably lower than the external pressure at the bow of the ship.

This stiffening of the bow becomes a matter of greater importance as the speeds increase. There is always the possibility in "bumpy" weather, when the height of the ship varies rapidly, that the pilot may let his pressure fall momentarily too low. The bow of the envelope then blows in and forms a curious concave cup shape in which it remains till the speed is reduced or the pressure is raised. No damage will probably be done so long as the reinforcement of the bow is not of such a nature that it will break and puncture the envelope. It may very probably be necessary to provide a separate small compartment at the bow and kept at a higher pressure than that of the rest of the envelope.

This would allow high speeds to be attained without a corresponding increase in envelope tension.

Planes.

In order to stabilise the motion of the ship it is necessary to provide the envelope at the after end with planes. These are provided at their after edges

with rudders capable of steering the ship either vertically or horizontally. The construction of these planes somewhat resembles that of the wing of an aeroplane. Fabric is stretched over a framework and is doped in order to render it taut. The surfaces are, however, practically flat and the loading is considerably less than that provided for in an aeroplane.

The planes are supported from the surface of the envelope by guy wires attached to suitable points on the envelope, and are prevented from pushing their inner edges into the envelope by skids or wooden bearers. The importance of the rigidity of this resistance to inward thrust is very often under-estimated. A small inward movement of the foot of the plane allows the plane as a whole to sit over a serious angle. This lack of rigidity in the planes has a serious influence on the stability of the ship.

The maximum intensity of air pressure occurs towards the forward edge of the planes, and it is therefore desirable that the leading edge should be short. The long narrow plane, increasing in width as it goes aft, is therefore adopted in preference to that of large aspect ratio which, although aerodynamically more effective, would be much more difficult to hold with adequate rigidity.

The planes of a rigid ship are attached rigidly to the hull framework. In the latest German ship these planes are made some six feet thick at the root and faired off into the rudder and tapered to the outer edge. They are, therefore, almost totally self-supporting and require no guy wires.

Fabrics.

The fabrics used in airships are of three main types:—

1. Gastight fabric, such as that used for gas bags of a rigid ship.
2. Outer cover fabric, of which the principal function is to form a rain and weatherproof outer cover to the ship, both as a fairing to reduce her resistance and to protect her internal bags from variations of temperature, due to radiant heat, and from deterioration caused by sunlight.
3. The envelope of a non-rigid ship requires a combination of both properties.

Gastight Fabric.—The lightest method of rendering a fabric gastight is the application of goldbeater's skin. This material is a membrane which, although water will easily pass through it, has a very pronounced ability to resist the passage of hydrogen. The skins are obtained from the mesentery of a cow, each animal contributing a piece which averages about 8in. by 20in. These skins are stuck to the fabric by means of glue or rubber solution, and are varnished to protect them against moisture and damage.

The gastightness of a non-rigid envelope is obtained by rubber proofing only. The same fabric has to fill the functions of outer cover, as stated above, and also has to withstand considerable stress produced by the internal pressure of the gas and by the tension of the riggings attached to it.

In order to obtain the necessary strength—and more particularly strength to resist tearing—a number of plys of cotton fabric are stuck together with layers of rubber solution between them. Fabric for small size ship can be given the required strength by two plys of cotton, the inner one being diagonal. Stronger fabric is usually made of three plys, the middle of the three being diagonal. The diagonal ply is formed by cutting strips of fabric and sticking them to the other ply so that their threads run at 45° to the threads of the main ply and to the length of the built up strip of fabric. These diagonal threads have a very pronounced effect in distributing a stress evenly over threads of the main ply.

The rubber is made into a thick solution and spread by a kind of scraping knife on to the layers of fabric before they are stuck together.

The rubber on the outer surface usually contains aluminium powder as this forms a surface that reflects much of the radiant heat, thus preventing rapid temperature change, and is also opaque to the light which would injure the fabric inside. It is usually found that the outer layer of proofing has perished so badly as to be easily noticeable before the strength of the fabric has become appreciably reduced by weathering.

Outer Cover Fabric.—Outer cover fabrics generally resemble the fabric used on aeroplane wings. It is necessary that after the outer cover is placed on the ship a certain degree of contraction should take place in order that the cover may be well tensioned to resist any tendency to flap. It is found that a contracting cellulose acetate dope is generally most satisfactory, but the extent of the contraction must be considerably less than that customary on aeroplanes. If the contraction is excessive it is liable to bring a serious crushing strain on the framework of the ship.

Considerable difficulty has been experienced in obtaining a satisfactory dope for the outer cover, but its functions in resisting light and heat and in providing a waterproof covering, are so closely analogous to those fulfilled by the latest aeroplane dopes that it is probable aeroplane practice will be adopted, the only modification being a considerable reduction in the amount of contraction allowed.

The outer cover of a rigid airship constitutes a very serious problem because the unsupported areas of the fabric are large, and it is of the utmost importance that no part of the fabric should flap or even tremble to a small extent. Such action would very rapidly increase and in the prolonged flights which these ships have to make, very serious results might follow any small flapping which was allowed.

Engine Requirements.

Our very extensive experience of airship flying, extending over nearly 3,000,000 miles during the war, has shown that by far the most fruitful cause of failure is connected with the engines. This is the case although a large proportion of the small difficulties which occur in aero engines are of a type which can be made good in an airship, but not in an aeroplane. The length of time for which an airship's engine is running continuously is very considerably greater than that of an aeroplane. The requirements to be expected from a good airship engine therefore differ from those of an aeroplane engine in several important respects:—

1. The engine must be suitable for running for very long periods without breakdown.
2. All gear on the engine must be arranged so that small defects can be made good in the air, the engine, if necessary, being stopped for a short period.
3. The fuel and oil economy, more particularly at reduced powers, is of far greater importance to an airship than is the initial weight of the machinery.

Although these differences between the requirements of airships and aeroplanes exist at the present time, they will be very considerably reduced as soon as the aeroplane develops into a machine of longer range and capable of flying with a smaller proportion of its power. The airship engine requirements of to-day are very largely the requirements which the aeroplane will call for to-morrow.

Useful Carrying Capacity.

The carrying capacity of an airship is perhaps the feature of greatest importance both from a Service and commercial point of view. The weight which is

available for bombs, passengers, merchandise, or fuel, depends upon the volume of gas contained by the ship and upon the weight of the ship's structure and all necessary parts. The volume of gas will increase as the cube of the linear dimensions of the ship, and it will be readily understood that the weight of the ship will not increase as such a high power. This indicates that as the size of the ship increases the proportion of her gross lift which is available for lifting capacity will also increase. The non-rigid ship having no hull structure will for the same size have a considerably greater proportion of available lift. It may be assumed that it is at the present time practicable to design both a rigid ship and a non-rigid ship which will be able to carry as useful load a weight equal to that of the ship, *i.e.*, 50% of the gross lift of the ship will be available for useful purposes. The size of a non-rigid which will give this ratio is approximately 500,000 cubic feet, and for a rigid approximately two million cubic feet.

For many commercial purposes there is much to be gained by carrying a given weight in several small ships rather than in one large one. For naval purposes, when the airship is used as a cruiser, her function is to carry observers and a W.T. installation for a certain distance at a certain speed, and a ship that will do this with a small crew is as effective as one with a big one. To this it must be added that the small ship can get away on a large proportion of the days when the larger ship would be weather-bound. The best figures which are available as regards the cost of our largest rigid and non-rigid indicate that some six of the non-rigids referred to above could be built for the same price as the equivalent rigid referred to.

Water Recovery and Use of Hydrogen as Fuel.

An airship which is making a long passage extending over several days has to contend with difficulties due to changes of temperature.

As the day advances she warms up and her lift will probably increase, due to of radiant heat by day and night, is often very great. Let us trace the history of a ship which leaves the ground in the early morning before sunrise.

As the day advances she warms up and her lift will probably increase, due to superheat and the petrol she has burnt. Unless she is prepared to keep herself down by using her elevators and flying nose down, she must rise and lose gas. Later in the day, when the superheat disappears, the ship may become seriously heavy due to the amount of gas she has lost. It is important, therefore, to reduce the gas lost, and this can best be done by avoiding the necessity of allowing the ship to go to a considerable height. For this it is necessary to take weight into the ship. This can be done by picking up water from the sea or by condensing the steam formed in the engine exhaust. The first method is only possible over the sea and by coming down to a low height. It even then presents considerable difficulty. There is, however, the advantage that a large weight of water can be picked up quickly when required. The weight of water that can be condensed from the exhaust is theoretically more than 20% in excess of the corresponding weight of fuel burnt, but it is found in practice that to collect more than about 80% of the petrol weight would necessitate very heavy condensers.

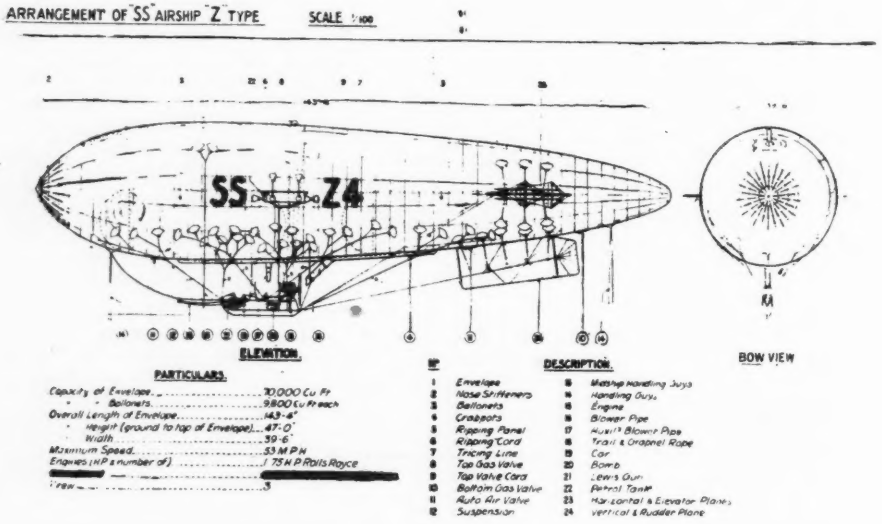
It is almost certain, however, that at many times during a long journey it will be necessary to discharge gas and arrangements have therefore been made to use the gas as fuel.

Experiments were first made in burning hydrogen alone as fuel in the engine, but it was found only possible to develop about one-third of the maximum h.p. of the engine. If a greater quantity of hydrogen than this was burnt serious detonation took place in the cylinder. Trials were, however, carried out by using both hydrogen and petrol, each mixed with the correct proportion of air. By varying the proportion of hydrogen mixture and petrol mixture, it is possible to obtain all powers up to the maximum of the engine. At the higher powers only

a smaller proportion of hydrogen can be burnt without trouble. No serious difficulties were experienced with the use of hydrogen as fuel, but it has been considered desirable that the gas should be drawn from the envelope at a pressure less than atmospheric in order to avoid any possible risk of fire. A spring-loaded non-return valve is fitted in the hydrogen discharge pipe and is loaded to a pressure considerably in excess of that which will ever be attained in the envelope. The suction of the engine is sufficient to draw the hydrogen through this valve, but if for any reason the engine stops no further hydrogen passes. The apparatus has been most thoroughly tested to eliminate risk due to fire, and it appears quite certain that at the present time the risks from a hydrogen fire with this gear are quite negligible.

Types of Airships Developed During the War.

The following slides show the gradual development of the present classes of British airships from the beginning of 1915, when the interest in airships was



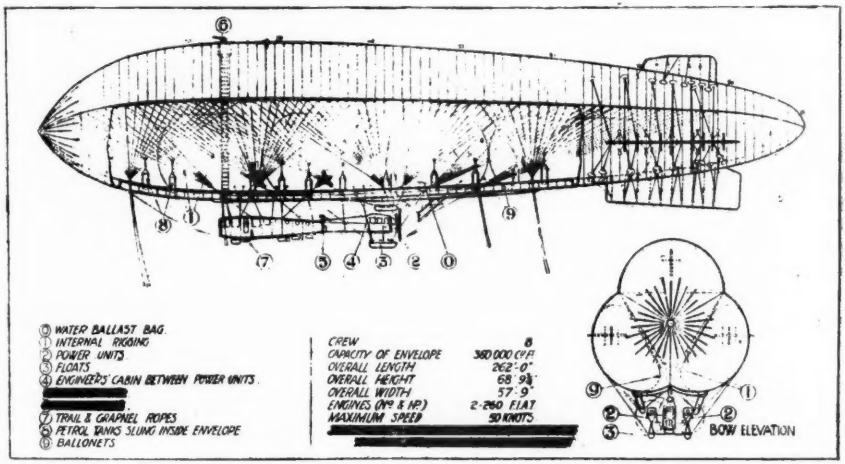
revived by Lord Fisher's decision that they might be made to form an important defence against the submarine. The first "S.S." ship was constructed by suspending a "B.E." aeroplane, stripped of its wings and tail, under a suitable small envelope. The trials of the first ship were made in less than 20 days from the time the instructions to proceed were received. The first flights were so satisfactory that the Admiralty gave instructions that the production of these ships was to proceed at once. There were at that time practically no firms capable of constructing airship envelopes or even of constructing airship fabric in anything like adequate quantities. The building up of this fabric and envelope constructing organisation almost entirely among firms of waterproof garment manufacturers, was not the least difficult or interesting part of our early airship development. It must be remembered that the firms who undertook this work were mostly totally unaccustomed to reading blue prints, as the whole of their cutting had been done from patterns made elsewhere. The "S.S." class of airship differed very slightly from the original ship in certain respects which had been found desirable on the first trial. A few cars of the "pusher" type which

generally resembled the nacelle of a Maurice Farman, were constructed by a private firm, but although they relieved the pilot of the propeller slip-stream, they did not prove as satisfactory as the older " B.E." type.

It soon became necessary to construct a ship of larger size and capable of lifting a greater load and of longer endurance. An envelope of the " Astra " type was obtained from a ship which had been built before the war as a Belgian millionaire's air yacht. A suitable car to take four men was constructed and rigged below it. This again proved a satisfactory preliminary experiment and was the beginning of the " Coastal " type. The envelope had to be re-designed, but the modifications made to the car were comparatively small. This class of ship was modified in 1918 to the type known as " C*," which had again a better shaped envelope and slightly better crew accommodation in the car.

The requirements for the " S.S." ship altered somewhat and it became desirable that the ship should be capable of landing on the water and also suitable

ARRANGEMENT OF "N.S." AIRSHIP. TYPE: No 7-12. SCALE 1/600



for being towed from a seagoing ship. For this purpose the " Zero " type of car was designed and constructed at the Airship Patrol Station near Dover. No alteration of an importance was, however, made to the envelope.

A ship larger again than the " Coastal " was found to be required for extended cruising in the North Sea and for work with the Fleet, and the " N.S." ship was therefore designed. It will be seen that she marks a distinct departure from the earlier classes. Her machinery is in a unit quite separate from the main car, which latter only carries the crew and navigating party. The petrol carried by this ship amounted, under certain circumstances, to about three tons, and the distribution of this load constituted a very interesting problem. In the first ship it was carried in a number of tanks attached to either side of the top lobe at a convenient distance above the top ridges. Access to tanks was obtained through the gun tube, which passes up through the centre of the ship, and then down a ladder way to a walking way along the top ridges. It was not, however, considered desirable that a man should have to be sent on top of the ship every time it was desired to turn on an additional petrol tank, and arrangements were made to lead wires from the power unit round the surface of the envelope to each

individual tank. This method operated satisfactorily, but difficulty was experienced with the hose conveying the petrol from the tanks to the car. The weight involved in the whole installation was also considerable. An alternative scheme was therefore designed and installed in the next ship. This provided large 90 gallon petrol tanks drawn up through the under surface of the envelope and suspended from the two top ridges by independent internal rigging generally similar to the main rigging. It is an interesting point that in the first few ships these tanks were made totally of fabric lined with a special petrol resisting dope. Experiments on these tanks had been proceeding for a considerable time, and one tank had contained petrol for over twelve months without serious loss of petrol or any apparent damage to the dope. It was found, however, after these tanks had been in use in several ships that an alteration in the constituents in the petrol had included something which gradually softened the dope and caused cracking and leakage. As it was probable that further alterations in the petrol might be made as the war proceeded, it was decided to be desirable to substitute aluminium tanks for these fabric ones, and metal tanks were therefore substituted in all later ships.

The development of the rigid airship shows fewer obvious features, although it may certainly be claimed that the improvements in strength and details of construction have been very satisfactory. The most obvious change has been with respect to the main keel of the ship. This keel, it will be remembered, has primarily to distribute the loads carried by the ship to the main transverse frames of the hull. In the earlier ships (as was the case in Germany) this keel was an external one of triangular section. Our next development was to eliminate the distinctive keel altogether, while in the "33" class the keel has returned, but as an internal part of the structure. It will be seen that with a rigid airship it is possible to provide spacious accommodation, both in the engine cars and in the navigating cars. It is possible for a mechanic to walk all round his engine, and except for certain parts below the level of the crankshaft the whole of the machinery is as accessible as can possibly be wished.

In addition to the space in the cars there is ample space along the whole length of the keel for the stowage of petrol tanks, bombs, or any other form of gear which may be carried. Scarcity of space for the stowage of articles or passengers carried is a difficulty which in no way enters into the airship problem.

I will, in one respect, depart from the restriction I imposed upon myself at the beginning of the lecture, and will point out where it will be most convenient to stow articles carried in airships of future types. It is considered as a result of experience probable that non-rigid should, in future, be of circular section. This is primarily because of the difficulty of adjusting and examining the internal rigging of the "Astra" type. This internal rigging is only necessitated by a concentration of load, and if this concentration can be avoided the extra complications should not be incurred. The loads carried are most conveniently disposed inside the ballonets, and can be carried by the fabric itself without any form of rigging whatsoever.

A further advantage from the pilot's point of view is that the position of the load or the air which replaces it when discharged does not vary and the trim of the ship is not affected.

Airship Handling.

Certainly one of the most interesting parts of airship engineering is connected with the handling of ships when they are not in flight. The problem of anchoring, mooring, towing, moving them over the landing ground into the shed, or securing them in temporary shelter, is one calling for as much resource and ingenuity in development as the construction of the ships themselves.

An airship, as you all know, makes her landing by flying slowly up to a landing party collected on the ground. She drops her trail rope which is taken by the landing party, led through a pulley block secured to the ground, and then used to haul the ship down until she can be taken in hand by the party. A number of guys, led from suitable points along the length of the ship, are then manned by detachments of the landing party, and the ship secured in this way can be moved about in any direction. This operation presents little difficulty so long as the ship is kept carefully head to wind. The direction of the length of the shed is, however, fixed and it may well happen that the wind is blowing across the entrance to the shed. Under these circumstances it is necessary to turn the ship broadside to the wind in order to get her into the shed. The process of entering the shed offers very considerable difficulty. A sideways force on the ship is many times greater than that due to the same wind truly end on. In the neighbourhood of the shed the wind is very seriously disturbed and forms large eddies. In many cases wind screens have been erected in order to break the force of a wind across the mouth of the shed, but it appears very probable that the unsteady flow produced by these screens renders the ship more difficult to handle than she would be if no screens at all were provided. In order to decrease the disturbance caused by these screens certain of them have been constructed with large gaps left at intervals, and others have been covered with expanded metal instead of corrugated sheeting. Both these devices tend very greatly to reduce the eddies formed by the screens.

The difficulty in handling the ship appears to be very largely due to gusts and variations in the strength of the wind, and also to the vertical component which the wind may have derived from the motion over sheds or screens and which tends to drive the ship down on to the ground.

Present opinion appears to incline to a complete absence of wind screens and the provision of side rails and travellers to which the guys of the ship can be attached. The difficulty of taking ships into their sheds must not, however, be unduly magnified. Ships working at patrol stations have frequently been taken into their sheds in winds of 35 m.p.h. Winds such as this would, of course, cause considerable risk to a rigid ship of the largest type.

Mooring.

Shortage of materials and the delays in shed construction rendered it necessary that in order to provide the great increase of airship bases required for the anti-submarine campaign, temporary arrangements should be made for mooring out the smaller airships. A very satisfactory means of arranging this was found by selecting suitable woods and cutting in them alleys leading up to small cleared spaces in which airships could be secured and protected from the wind by the trees. As long as trees of sufficient height were available it was found that this system proved most satisfactory, and many small mooring-out camps were established and satisfactorily protected their ships against winds of over 60 m.p.h.

The size of ships which can be protected in this way is, of course, limited by the height of the trees. Other arrangements for mooring ships are therefore necessary.

Single Wire Mooring.—The most obvious method of securing a ship to the ground is to attach her by a wire led from a suitable point in the ship to a fixed point on the ground. When secured in this way, it is found that an airship requires constant attention and steering in order to render her reasonably steady. It is found that considerable improvement is obtained by adding to the wire a dragging weight, or when secured over the water a drogue, which will, to a considerable extent, check although not rigidly resist the lateral motion of the bow of the ship. Variations in wind force are satisfactorily taken up by trimming the ship so that she lies at a small upward pitch. Any increase in wind force then

causes an increase in her lift quite adequate to balance the increase in her resistance.

Three Wire System.—An improvement on this single wire system consists in securing the mooring point of the ship to the head of a pyramid formed by three long wires. The lift of the ship raises these wires off the ground, and if she is given a slight upward pitch she is able to resist the action of a steady wind. This system has proved very satisfactory.

Mast Mooring.—In both the foregoing systems there is considerable difficulty in changing crews or pumping water or gas into the ship. A much more convenient arrangement is made by securing the ship to the head of a comparatively short mast. Two methods of doing this have been proposed. The most obvious one is to secure the ship by her extreme bow point. This is a simple matter in the case of a rigid ship, but a non-rigid requires reinforcement at the bow.

Towing.

The first towing experiment was carried out in 1912 when one airship broke down and was towed home by another. The towing ship landed alongside the disabled one and a wire was taken from her to a suitable point on the latter. The ships then rose and no difficulty was experienced in the towing operations. This operation in itself has not been used since, but it offers attractive possibilities for conveying large weights of material at a comparatively slow speed when the airship tug may tow a number of air barges after her.

The principal use which has been made of towing during the war is to tow an airship from a light cruiser or patrol boat. This operation in itself presents no serious difficulties. The ordinary trail rope forms a satisfactory tow line, but it is absolutely necessary that the airship should be continuously steered while in tow. It has often been suggested that an airship which could be towed without its crew would be of considerable value. Although such a process is possible with a kite balloon, the airship which possesses considerably less directional stability, and also has not automatic gear for maintaining the pressure, would have to be radically altered before she would be suitable for towing empty. If altered so as to be stable enough to tow without crew, she would scarcely be satisfactory for ordinary flight.

Anchors.

The problem of anchoring a ship, *i.e.*, securing her without the assistance of men on the ground, is one which is mainly of importance if it is necessary to prevent an airship drifting when broken down. Various forms of grapnel have been used from free balloons for many years, but an airship, which is many times greater weight, is found to acquire such momentum when drifting that she will pull out or break any ordinary grapnel. The problem of getting hold of the ground from an airship above it is much more difficult than appears at first sight. An ordinary grapnel will be dragged a considerable distance before it catches a tree or anything giving a suitable hold. A proposal was made many years ago that the airship should fire a form of harpoon into the ground and ride to that as an anchor. This question was again raised in 1916 and rough designs were therefore prepared to determine the best form of harpoon which would sink into the ground and then open so as to exert considerable resistance to being pulled out. The principal difficulty lay in obtaining sufficient penetration, and experiments were therefore carried out to determine the form of head which would give the best penetration. Several samples were dropped, and at the conclusion of the tests attempts were made to pull the dummy anchors out of the ground. This proved a very difficult business, and the idea of a solid grapnel which would penetrate the ground sufficiently far to jamb itself securely, obviously presented itself. Considerable success was obtained. The head of the anchor was made of

cast iron with a long tubular shaft, and the wire was secured to a point close under the head. When this anchor had penetrated the ground to a considerable distance and the ship had drifted so that the pull came fairly oblique, the wire cut into the ground and tended to pull the whole grapnel sideways. To such an action a very satisfactory resistance was obtained. It was still, however, found that a heavy ship drawing her trail rope suddenly taut against a grapnel such as this, either parted the trail rope or ran considerable risk of damage to the mooring point of the ship. It was, therefore, necessary to devise some suitable means of gradually absorbing the energy of the drifting ship without producing any excessive impulsive tension on the rope.

The problem of anchoring over the sea is a comparatively simple one. An ordinary drogue, formed much like a parachute, has quite a satisfactory effect in reducing the speed of a drifting airship down to two or three knots. It was thought that if an anchor was dropped so as to be on the further side of the drogue, the anchor would secure itself satisfactorily to the bottom of the sea, and the drogue would then act as a weight to resist the upward component of the pull of the ship. Under these circumstances, however, it is found that the drogue has a considerable tendency to pull out of the water. A drogue which is kept moving through the water can easily be arranged to keep itself full.

It is not easy to pull a drogue such as this out of the water when it is desired to get under weigh again, and a slip has, therefore, been arranged whereby the drogue is secured to the end of the trail rope and can be spilled from the ship.

There is much more which might be said about the handling arrangements connected with airships, but as the time available is short it is hoped that what has been given will suffice to show how far airships approach the completeness with which seagoing craft can be anchored and handled. There is, however, one important point to which it is desirable to draw attention in connection with the development of large aircraft. It is often advanced as a handicap inseparable from the airship that she requires a large handling party. When all things are considered for aircraft carrying the same disposable load the advantage appears rather to be with the airship. An airship, however large she may be, can be landed with as little difficulty as can the smallest airship. She can be brought slowly over the landing party and can be taken in hand on any ground which is reasonably free from obstruction. She can then be made considerably lighter than the air she displaces so that the force which the landing party has to exert is mainly a downward one. Provided the aerodrome is clear and the surface good enough for the landing party to walk over, the ship can then be carried into her shed.

Compare this with the large aeroplane which must necessarily have a considerable horizontal velocity at the time it touches the ground. It must have a clear space of smooth hard ground to run for a considerable distance, and when it has come to rest it presses on the ground with the whole of its total weight. Under these circumstances its handling over any but the most carefully prepared ground is a matter of considerable difficulty.

The difficulties connected with landing and handling an aeroplane on the ground will, it is considered, increase very rapidly with size, and the margin in favour of the airship is likely to increase rather than decrease.

I have tried to crowd into one evening what really requires many very carefully prepared lectures to give a reasonably correct impression of the work which has been done even during the war. You must only, therefore, regard this lecture as a peep into airship engineering, a science which those who have experience of it realise to be at least as complex and involved, but also to have at least as great possibilities, as the corresponding aeroplane work. The man who knows much more about the aeroplane than the airship must realise that his view is distorted, while everyone, if he wishes to gauge the relative possibilities

of H.A. and L.A. craft, must remember that although the airship started first, the energy and talent devoted to its development has been incomparably less than that from which the aeroplane has benefited, more particularly in very recent times. One must be careful in comparing two things at widely different stages of development.

If the lecture has succeeded in stimulating in this our premier technical and scientific aeronautical institution, a new interest in and a greater insight into airship development, I am certain that the onus laid upon me by the Council, when they invited me to prepare this discourse, will have been satisfactorily discharged.

THE SUPPLY OF METEOROLOGICAL INFORMATION.

BY LIEUT.-COL. H. G. LYONS.

Information relating to weather and climate has always attracted the attention of the inhabitants of all countries, as is shown by the number of popular sayings which relate to the weather and its changes in civilised countries, and by the general identification of atmospheric phenomena with gods and demons among savage races.

As more accurate knowledge was attained, and the science of meteorology has developed, the increase in our knowledge has carried the subject somewhat beyond everyday use, and there is some uncertainty as to the demand that may reasonably be made on meteorologists. In many directions the importance of the atmosphere in its many moods has been forced upon us recently, and during the past five years operations in many parts of the world, and especially the rapid development of aviation, have made new demands upon all those who make a study of weather conditions, and who devote themselves to the investigation of the numerous and varied problems which the atmosphere provides. More detailed information is asked for, greater precision is required, and the regions over which such information is wanted are ever growing wider.

The difficulties and risks of aviation are so greatly increased by unfavourable atmospheric conditions that the aviator is naturally strongly impressed by the importance to him of the best and fullest meteorological information that he can obtain; and he may be led to assume that the information that he requires must necessarily suffice for all other activities and all lines of investigations.

The truth is rather that the fullest meteorological information of all kinds is needed, so that it may be studied and worked upon by trained meteorologists in order that we may learn more of the principles underlying the phenomena that we observe, and from this standpoint be better fitted to advise aviators as well as all others to whom weather and climate are factors with which they have to be reckoned.

Though aviation makes probably larger demands on that part of meteorology which deals especially with weather, that is, with the short period changes of meteorological conditions, it does not thereby cover the whole field of meteorology any more than the chemistry required in the work of any branch of chemical industry necessarily covers the whole field of chemical science. The same phenomena which are of importance in aviation are among those which the meteorologist studies for the progress of his science. The interest and the importance of the force and direction of the wind at various altitudes above the surface of the earth, which are observed by means of pilot balloons, shell-bursts and other methods, are not limited to the aviator alone. The forecaster needs them in his work, in gunnery they are carefully observed and utilised, the meteorologist in his study of the physical conditions of the atmosphere requires them as data from a region where friction with the earth's surface, and heating and cooling of the air by convection, do not complicate the problems with which he has to deal. It is indeed impossible to say that any particular meteorological study is unnecessary or useless for aviation, for gunnery, or for any specific application of meteorological science. Measurements of wind, temperature, humidity at various altitudes, taken with all the precision that can be attained are indispensable to the meteorologist who is seeking the principles which underlie the phenomena that we observe, and which, when determined, represent a definite advance in our

knowledge and thereby in our powers of practical application. Observations made in one line of investigation will often, in practised hands, lead to advances in knowledge which are of the utmost importance in their application in quite different fields. Thus the observations which Major G. I. Taylor, F.R.S., made in 1912 on board s.s. "Scotia," which was chartered for studying the distribution of drift ice in the North Atlantic, have led him to most important advances in our knowledge of eddy motion in the atmosphere, which has thrown light on the conditions which determine the formation of mist, fog and low cloud, thus materially advancing our knowledge of a part of one subject which is of supreme importance to the aviator.

The observation of the trade winds in the South Atlantic, the rainfall at Zanzibar, the excess or defect of pressure in Northern Egypt, the amount of the snowfall in the Himalayas, meteorological conditions in South America have all been utilised to form a basis for prediction of the Abyssinian rainfall and therefore of the Nile floods or the monsoon rains of India. There is a connection between these various groups of information more or less close, which for the time being furnishes us with an indication of the changes which are in progress and which result in more or less favourable rainfall in India and Abyssinia.

The observations which are employed in this way have not been taken with the sole object of solving these particular problems, but are part of the common stock of meteorological information which is being accumulated day by day and year by year for use by meteorologists as the need may arise. In the same way, too, the study of the observations which have been made and are being made in the upper air is being actively prosecuted and will be brought into use as an aid in elucidating many questions which still await a full answer.

Thus all the meteorological information which is collected for any purpose should be made accessible to all workers since the same material will be utilised for many different purposes. Publication in the forms which have been adopted after careful consideration as being the most suitable is one way, but there will also be a mass of original records, special investigations and other researches to which the working meteorologist should have access and to which he should be guided by an effective system of registration and indexing. The material is so vast and so varied that it soon becomes unmanageable unless an effective means exists of tracing readily the different parts of it.

In the Meteorological Office there are records extending over more than half a century, and besides these there are hundreds of investigations which have been made from one time to another for various purposes. In the present conditions of a wider utilisation of such information a more complete and more detailed means of leading the inquirer to those pieces of information which bear most directly on the object of his search is being introduced. But to render this really effective it must include not only the material that is stored in a single institution, but it must also indicate where any additional information may be found elsewhere.

Next to the importance of realising that all meteorological information must be available for use in all branches of study, and all kinds of application, is the need for general co-operation on the widest lines in all parts of the subject. The position of any particular station on the earth's surface, whether in the polar, temperate, or tropical regions, its situation on the coast, in the interior of a continent, or an oceanic island, near sea level, or on a mountain range, all these and many other factors impress their influence on the phenomena which are observed at it. Before we can utilise such information, therefore, we must know all about the station from which it comes, and in order to disentangle from the results obtained the effects of the various factors, we must know precisely how the observations have been taken and what their accuracy may be.

This is ordinarily attained by taking such observations at certain hours, by

certain methods, and with specified types of instruments, so that the results of one station shall be, so far as possible, comparable with those of another. Absolute uniformity of practice may not be everywhere attainable, but ever since international co-operation in the study of meteorology has been practised the greatest measure of uniformity has been the constant aim of the meteorologists of all countries. It has been recognised generally that for any service to adopt different hours of observation or different methods of observing would be to increase the difficulty of utilising the results in conjunction with those of others and thereby to diminish the return for the expense incurred in their collection. Such organised co-operation is the more necessary since the meteorologist is always in the position of an intelligence officer, for he depends almost wholly on the information which he can procure and collect from far and wide for his material. He seldom utilises his own observations alone, but is usually dependent on those which have been taken by other workers, probably in other lands and under very different conditions. The phenomena with which he deals, even those which are rapidly changing, cover very large areas, for cyclonic depressions are often more than one thousand miles across, and they may move at a rate of 30 to 40 miles an hour. There must therefore be the fullest co-operation between observers of all countries and the greatest uniformity of practice in observations, in instrumental equipment, and in methods of summarising and transmitting information, if the best results are to be obtained.

All meteorologists have long recognised that the weather of any particular region is only the local result of causes which belong to the general circulation of the atmosphere, so that a collection of the meteorological data of the globe was a first necessity.

This is being provided in such a form as can be produced at present by the publication of the Meteorological Office, the "Réseau Mondial," which gives the pressure temperature and rainfall for each month at a number of selected stations, two for each ten-degree square being taken wherever possible. This publication, of which three years, 1911, 1912, 1913, have appeared, is only possible because of the uniformity and co-operation which has been achieved by international effort.

Changes in these international arrangements will no doubt be necessary from time to time, but all experience shows that they should not be made hastily. Moreover, a consensus of favourable international opinion is difficult to obtain since social and administrative conditions in various countries differ so as to make readjustment difficult. As usual some compromise is usually inevitable, but the main principle of increasing wherever practicable the uniformity of practice already attained must be kept in the foreground.

The next point for consideration in the supply of meteorological information is that for one special class of that information rapidity of transmission is of the highest importance.

That division of meteorology which deals with weather is primarily concerned, at least in extra-tropical regions, with the changes which take place from hour to hour and from day to day; and these changes take place often with great rapidity and spread quickly over large areas, so that if they are to be anticipated and warnings issued of such coming changes as little time as possible should be expended in the collection of reports and the issue of forecasts and warnings.

In this country forecasts have long been prepared thrice daily, from observations at 7 a.m., 1 p.m. and 6 p.m., but with the increase of aviation during the war and the necessity for the issue of forecasts of the weather at an hour before the day's plans for operations were under consideration, an additional forecast and report based on observations at 1 a.m. was introduced, and has been continued up to the present time.

For years past the meteorological services of most European countries, as well as those of India, Canada, the United States, Egypt, Japan, and some others,

have issued daily weather reports and maps of their area and of the surrounding regions, interchanging information by telegraph under international agreement. Europe was in this way fairly well provided with information of current weather from a large network of stations, to which were added in 1909 reports from ships of the trans-Atlantic steamship lines.

Under present conditions these international services can be and have been for the most part resumed, but the new demands for a quicker and more frequent supply of information are much larger and more numerous than those of five and six years ago. The forecaster must now receive his reports within an interval of not more than an hour after the observations have been taken, and for them to be utilised to the full, his deductions from them should be available half an hour later.

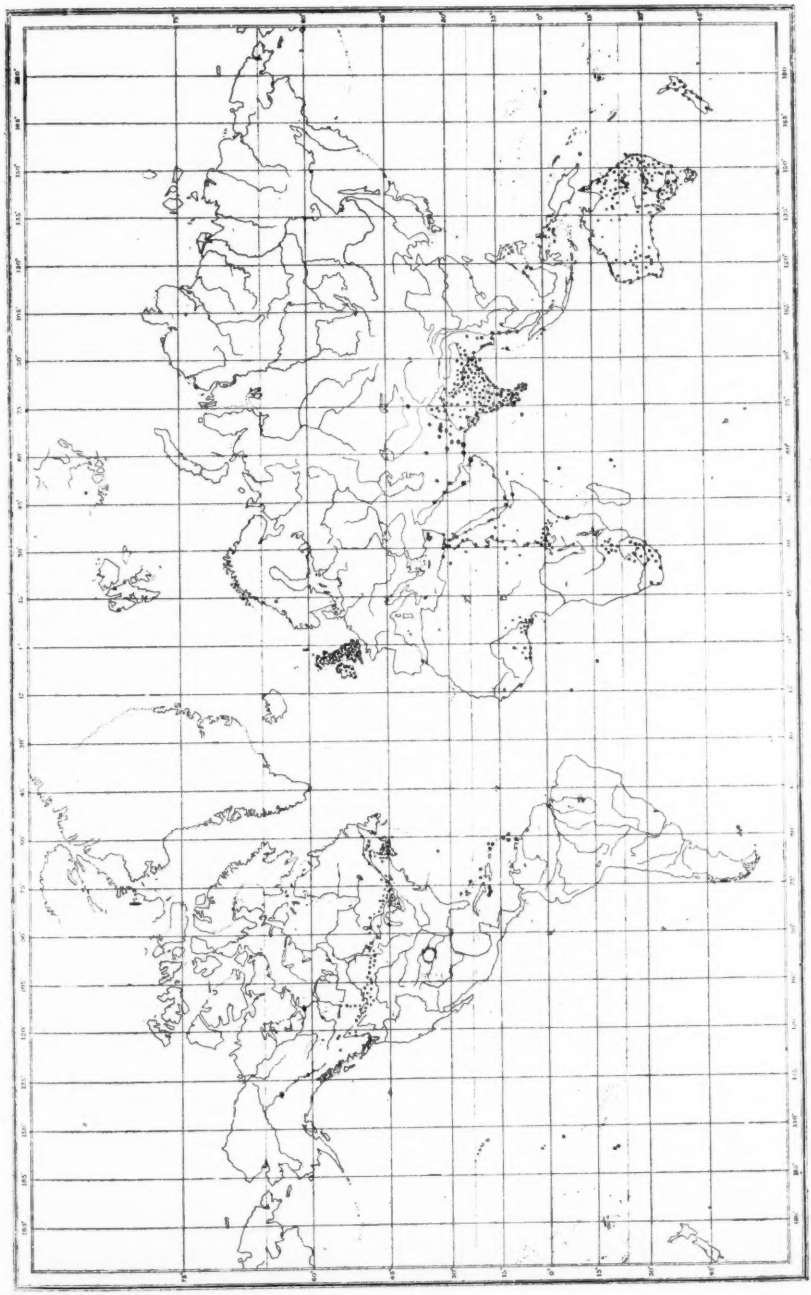
This means that a large amount of information has to be transmitted at fixed hours four times daily, and as all observations are, so far as can be arranged, synchronous for the purpose of being directly comparable, all neighbouring countries are occupied in the receipt, dispatch and interchange of reports at the same time. Wireless telegraphy is going to assist greatly in this transmission, but it has other and numerous calls upon it, and the necessity for meteorological reports being transmitted at definitely fixed hours makes international co-operation and uniformity of practice all the more essential. Again, the margin of time available for decoding reports, plotting the information on a map, considering the meteorological conditions therein represented, and deducing the probable changes and developments, is very small, and every cause of delay must be avoided if the necessary promptitude is to be attained. Services which employ special scales for reporting observations or special methods of coding; recipients who demand reports in special form; all these and other deviations from a fixed procedure cause loss of time when every minute is of importance, and as far as possible such complications should be avoided.

Local conditions may greatly influence the weather which is experienced and these cannot well be taken into account in the forecast issued by a central institution. To do so would make the forecast message too long, and would necessitate a very large number of special forecasts being drafted for which there is no time. Such local characteristics are best allowed for by the local meteorological officer, who receives from the central institute a forecast of the general conditions, and so much of the observational material of the reporting stations as he may require. With this he can edit, amend, and amplify the general forecast, so that it becomes a special forecast for his own particular area, taking account of its peculiarities, and in this his local knowledge should materially aid him.

But whether it is a forecast issued from a central office or from a local secondary forecasting station, some technicalities can hardly be avoided; the prevailing or anticipated conditions must be described in a few lines at most, and if precision as well as brevity is to be attained, technical terms cannot be avoided.

The daily weather report which was issued before the war from the Meteorological Office, was a document which had grown up gradually and by successive changes. It had been the rule to publish with the map the statistical material which had been used in its production, so that the reader could check its correctness, and, if he pleased, draw his own deductions from it.

But under service conditions something simpler, plainer, and more direct in its presentation of the opinions of the trained meteorologists who prepared it, was needed. Those who had to make use of the daily weather reports were usually far too busy to wish to study the statistical material before accepting the meteorological opinions which were offered to them. They wanted a direct statement of expert opinion of which they could make use in preparing their own plans of action. The desire for such expert assistance was also shown by many requests that forecasts should be expressed in " perfectly simple and non-technical



British Empire Meteorological Stations.

language." To this very reasonable request it was not so easy to accede as it may seem. Such expressions as "a depression advancing from the westward," "a secondary depression developing over the Channel," "an anti-cyclone spreading northward," are more than mere statements of fact; they convey to all who are acquainted with meteorology much additional information depending on the weather conditions described, which it would take several paragraphs to describe simply and in non-technical language. The same is true of every technical subject; whether it be a branch of science, of technology, or for that matter of any form of human activity. Everywhere technical terms come into use, since they are convenient and economical; and they describe a certain set of conditions more precisely than can be done by any circumlocution. But to meet these requirements as far as possible, a special set of weather reports was issued in the early morning, at noon, and in the afternoon, to all who required them, and from these statistical data were omitted.

Now that hostilities have ceased, the opportunity has been taken to revise the daily weather reports in order to make them more useful and more convenient for reference. The simplified morning report of war days has been transformed into a British daily weather report, in which all the information from the United Kingdom is included, and is issued before noon. Later in the day an International daily weather report is issued, in which all the data from foreign countries appear. In addition, a special two page supplement, containing all upper air observations from the observatories of the Meteorological Office and meteorological stations of the Air Ministry as well as from some in France, is published daily at noon.

These cannot, of course, replace the telegraphed reports and forecasts for recipients out of London, but they provide the material for reference and future study. Under the present conditions of world-wide flying, it is not the weather service of this country alone that is of importance. A large part of the world is dealt with more or less completely by the different meteorological services, though the density of the networks of stations naturally varies widely. However, there are already large areas over which the weather conditions are reported and studied daily in greater or less detail; and this study will certainly increase under the new demands that are being made upon it.

In some regions the problems are less complicated than in others, for as we approach the Tropics for example, weather conditions usually become less disturbed, and at certain seasons, at any rate, day follows day with but slight difference, and important disturbances are rare. In the Mediterranean, from May or June to the end of September, settled weather is the rule over the Eastern half at least; and North-Eastern Africa presents very stable conditions, except occasionally in the northern part during the winter months, and also south of latitude 15°N. in the summer, when the Monsoon rains spread northwards over the Sudan. India can show similar cases.

Now the meteorological services of all regions will have, in addition to the study of their own area, to assist in the provision of information for such air routes as pass them, and, in co-operation with the other services in the Empire, investigate those meteorological problems which are continuously arising, and especially those which the introduction of aviation on a large scale has now made more urgent.

These services already issue their daily weather reports, but probably they too will find that some modification of them is necessary to meet these new demands and enlarged requirements.

Whenever forecasts have to be prepared, reports from many stations must be collected and a weather map drawn; and if drawn it should be issued to all whom it can reach in time. Thus on every war front, daily weather maps have been regularly issued, often several times daily, and at this moment one is furnished to the British Force in North Russia; and in all future operations the same will be required.

This intimate co-operation between the different meteorological services which aviation necessitates, increases the importance of imperial and international consultation, in order that information may be provided on all routes, and at all stations as nearly as practicable in a common form, and with the least possible delay.

The foregoing remarks relate particularly to that branch of applied meteorology which may be termed the weather service; the reports on current weather conditions and the estimates which are formed of the changes which will take place in them and the times at which they will occur. These, we have seen, may usually be amplified and improved for any particular station by a meteorologist who is acquainted with local conditions and has determined how they re-act upon different types of weather.

This is the class of meteorological information which appeals most directly to the aviator and is of the greatest importance to him.

But besides reports on the current weather, there exists also the great mass of information which has been accumulated during many years by all meteorological services and observatories, which is made up of daily observations taken at two, three, or more, fixed hours, and which has for its object the provision of material for the solution of the problems of meteorology, and the general advancement of the science.

From this, the general meteorological character of a station or a region may be determined, as well as the change which takes place from month to month. Essentially it is the long period phenomena which are considered; rapidity of transmission is not of the same importance as it is in a weather service; mean values of temperature, rainfall, etc., are obtained; the extreme values observed are noted, and generally it is climate rather than weather which is studied.

Aviation has a number of questions to which this material can supply the answer, but much of it has to be re-arranged to put it in the most suitable form required by new demands. The frequency with which a certain temperature is attained, the number of days on which the wind blows from a given direction with a certain force, the number of days on which fog or mist occur, and the hours at which they are most prevalent—all this and much more information is generally obtainable from these records; but it has usually to be extracted and compiled specially. No one form of record will suit all the inquiries that may arise, and the information must always be worked up to meet special requirements.

Seeing how voluminous the material is, this is no light task, and, moreover, it demands skilled direction if the best use is to be made of the data which are to hand. All published material is not of the same value, and manuscript unpublished material may contain errors, or require correction before it is utilised, which may be overlooked by anyone who is utilising it mechanically.

Now that meteorological records are being more largely worked upon and will continue to be worked upon in the future, it is of the highest importance that there should be at a central institute as complete a collection of them as possible. Also, that at that institute, a highly efficient system of registration and indexing should be in operation, so that inquirers and students may be referred readily to all sources of information, whether published matter, manuscript records, or investigations that have been carried out and then filed away. The last group is not the least important, for work of this kind may be needlessly repeated unless there is a ready reference to what has already been done.

There is a large amount of information of such a statistical character published in this country already; weekly and monthly weather reports of the United Kingdom appear regularly; but for the war the climatological atlas of the United Kingdom would have been published by the co-operation of the Meteorological Office and the Royal Meteorological Society. Pilot charts of the North Atlantic and the

Indian Ocean appear monthly, and contain much information relating to these ocean areas, which have been collated from the valuable meteorological logs contributed by ships' officers.

No doubt, in view of the new demands made upon meteorology, some of these forms of supply need revision to make them more widely useful; average conditions can be set out in publications appearing at moderately long intervals, while current information must be distributed quickly and in a less cumbersome form. Inquiries are already being received with increasing frequency, but provision is being made to deal with them on a larger scale and to encourage them.

The British Empire possesses a very numerous and widely flung network of meteorological stations, numbering about 1,000 in all, besides those which record rainfall only, and the ships which keep meteorological logs; these stations are organised under the meteorological services of this country, of the Dominions, of India, and of the Crown Colonies, so that they furnish us with opportunities for investigating almost any problem that may arise in meteorology, if competent meteorologists make full and proper use of them. Bermuda, the Windward Isles, St. Helena, Ascension Island, the Falkland Islands, and South Georgia, provide a chain of stations from which, although they are not quite so conveniently situated as could be wished, the meteorological conditions over the Atlantic Ocean may be investigated, and the supplementary observations taken on sea-going steamers can be controlled. Their results can be compared with those which the islands of the Indian Ocean can provide, viz., Socotra, Seychelles, Mauritius, and Keeling Island, or again with those from the numerous islands of the Pacific.

A large number of our Colonies are situated within a few degrees of the equator, and the meteorology of this zone has been by no means adequately investigated as yet. The striking agreement which has been shown to exist between the curve of 25 years' gauge readings of the Victoria Nyanza, and the sunspot curve for the same period, suggests that this periodicity is worth investigation at any other places near the equator where long records are available. The life-history of the tropical storms, which often pass as cyclonic depressions of greater or less intensity into higher latitudes, demands close study, and the co-operation of meteorologists of East and West Africa with those of the West Indies and of the Western Pacific and the South China Sea should be productive of much that will increase our knowledge.

A better means of co-ordination and co-operation among all these services and sources of supply is highly desirable if the best use is to be made of the meteorological resources of the Empire. A conference of the heads of these different services should be held as soon as can be arranged, in order that views may be interchanged and plans matured for the collection and interchange of information, and the investigation of the various problems that arise. In many parts of the world more data are required to increase our knowledge in special directions, and if these questions are attacked by concerted action on an arranged plan, the prospect of their early solution is greatly increased.

Africa has been mentioned as the site of two air routes, and here there are many subjects of great meteorological interest. The Egyptian and Sudan Service has, during 15 or 16 years of its existence, thrown much light on the conditions prevailing over North-Eastern Africa.

In West Africa and the French Sudan, our information is less complete, but some observations recorded by M. Hubart, indicate that above the south-westerly monsoon air-current of the west coast, there prevails throughout the summer, at an altitude of about 2,000 metres, a steady E.N.E.-E.S.E. current, which agrees well with what is deducible from the calculated distribution of pressure in that region, and is a fact of considerable importance. The direction of movement of the violent thunderstorms and tornadoes in this region of the equatorial belt suggest that it is determined by this upper air-current, and the further study of this and

other related questions by more extended and carefully planned observations should yield valuable results.

It will be clear then that the supply of meteorological information involves a large and intricate organisation. Part of this is international since the regions dealt with far exceed the limits of a single country, and international arrangements are difficult to make since many points of difference arise which are due to the different administrative and social conditions which prevail in each country. Some compromise is nearly always necessary in the first instance, and it is only gradually that more complete accord and uniformity of practice is attained. For these reasons international meteorologists are loth to change international decisions which have been arrived at unless there is general agreement in favour of the change or a very urgent necessity compels the surrender of some of the uniformity already achieved.

National co-operation offers fewer difficulties in the way of uniformity, but in so widely distributed an Empire as ours local conditions vary so widely that more points of difference arise than would occur in a more compact geographical location. Conferences of the directors of all the various British meteorological services are the natural means for obtaining greater co-ordination, and to some extent these have been provided by the periodical International Conferences of Directors or meetings of the International Meteorological Committee. There are, however, greater advantages to be gained from imperial meteorological conferences which can easily be held just before the international meetings. The present time is very suitable for such a first conference and it is to be hoped that nothing may prevent it from being held at an early date.

Within each part of the Empire complete co-operation where more than one service exists should be the rule, for anything else would be wasteful and destructive of efficiency.

The next stage in organisation is to place all information at the disposal of workers and investigators so that it may be most conveniently and expeditiously used by them. Here both centralisation and decentralisation come into play, for a central institute should receive all material that is of the character and quality for serious meteorological study; and should also hold it at the disposal of all that desire to consult it, facilitating such use by modern methods of registration and indexing.

Much of this material can be worked up within a short period and printed in such forms as have been or may be found most suitable, and these should be distributed to all centres and institutions where they will be used and consulted. This is already done with all publications of the Meteorological Office, but an expansion of the work can easily be effected.

There will still be much material which will not be so produced, but will be preserved for reference; also for special purposes the original records must be reworked to furnish data in the form most suitable for this or that special investigation, or particular inquiry. It is impossible to keep information ready to hand in the form to suit every demand, and some of them require considerable preparation before they can be met. These inquiries can sometimes be dealt with by reference to the published records, and in this case can be satisfied at such centres and institutes as possess a meteorological library of reference. At other times extraction from original documents and retabulation is necessary, which should be done under superintendence of a trained meteorologist. For such work a central institute where the staff is accustomed to such work provides the readiest and most efficient means of supplying such information.

The method of supplying all information relating to current weather has already been outlined. A central institute receiving all incoming information by telegraph, telephone and wireless messages can send forecasts of general condi-

tions likely to develop over definite areas to secondary meteorological centres, who would also receive so much of the original observations as they required to complete their own maps. With this they would be able to provide warnings and forecasts for local needs and to reply to any inquiries that might be made.

Squalls, thunderstorms, and sudden changes of any kind would be reported by stations observing them to others and so keep the local meteorologists warned of approaching developments.

As the organisation of one country is left for that of another, arrangements will be made for aviators to receive the information that each has to supply, and a common form for this is easily devised.

Lastly, it has to be borne in mind that the material from which the desired information is derived has to be drawn from over wide areas; that many of the phenomena with which it deals are in rapid development; that the material has to be collected for use by a trained staff; and that much of it has to be worked upon and re-issued with the greatest promptitude attainable. To do this efficiently and economically demands wide and full co-operation, careful co-ordination of effort, and ready sharing of all information.

PROCEEDINGS.

TWELFTH MEETING, 54th SESSION.

The twelfth meeting of the Session took place on Wednesday, March 26th, in the Theatre of the Royal Society of Arts, London, Brigadier-General E. M. Maitland, D.S.O., R.A.F., presiding.

The CHAIRMAN said it was a great pleasure to him to introduce their lecturer, Lieutenant-Colonel Cave-Browne-Cave, although he needed no introduction, as his aeronautical record was known, he had no doubt, to everyone in that hall. He was specially selected in the early days—years ago they seemed now—before the war to study this problem of airships, and his association with airships dated back to the year 1912. When he joined up at Farnborough he studied the army airships in that year, and during that time he was associated with all the problems that arose at the commencement of a new branch of aeronautics—as it was then—and on the outbreak of hostilities he took over the very important duties not only of designing but the production of non-rigid airships, and the airship service owed Colonel Cave-Browne-Cave a deep debt of gratitude for the work he did in those strenuous days. Colonel Cave-Browne-Cave was a very remarkable man. When things went wrong, when dark clouds loomed up on the horizon—and the airship service had had its ups and downs, like every other airship service—Colonel Cave-Browne-Cave was never bothered. He went on his way quite undisturbed, imperturbable, and they would probably find him unruffled now that he was faced with the problem of giving a lecture on a formidable occasion like that. He (the Chairman) would like to take that opportunity of saying that no one individual, in his opinion, had done more for the development of airships in this country than their lecturer of that evening. As regarded the lecture itself, a great deal had been said in and out of the Press about our rigid airships—what they were going to do and what they had done. He read in a paper the other day (he would not mention its name) that two rigid airships we were producing to-day, one at Barrow and the other at Selby in Yorkshire, were the biggest airships in the world and were going to fly to America and back in two days. That, he was afraid, was rather more in the nature of a pious hope than anything else. The object of the lecturer was to put before the audience the exact extent to which airship development had arrived at the present date, so that at the end of the lecture they might be in a position to estimate for themselves what airships could do, and were likely to be able to do commercially in the future. The airship service was principally concerned with anti-submarine operations during the war, and, therefore, what it had done was of necessity more or less of a mystery. Nothing had been written nor said about what work had been done during the war. The airships had flown under all kinds of conditions, out at sea, without being in sight of land at any time from early morning till just before dusk, and they had flown 2½ million miles during the war, and escorted a very great number of convoys. That work had been of very great value to this country. The airship had undoubtedly made good. They flew very long hours. One of them the other day did 101 hours 20 minutes non-stop endurance flight—a record for this and every other country with the exception of Germany. But this was Colonel Cave-Browne-Cave's lecture, and not his, so he would ask him to get right ahead with it.

Lieutenant-Colonel T. R. CAVE-BROWNE-CAVE then delivered his lecture.

DISCUSSION.

The CHAIRMAN said the lecturer had covered a very wide field of discussion, and he thought it was an excellent opportunity to have a very interesting discussion on the different points he had referred to. He would like to call upon Mr. Cole, who was one of the leading designers of rigid airships in this country, to make a few remarks.

Mr. COLE said he thought those who had to do with the design of airships were convinced that the only successful development of lighter-than-air craft would be by means of the rigid type, or perhaps the large rigid, with the smaller non-rigid for certain purposes. The lecturer stated that the non-rigid airship, having no hull structure, would, if the same size as a rigid airship, have a considerably greater proportion of available lift. He thought no one but an enthusiastic amateur would think that a non-rigid airship could be compared with a high capacity rigid. The maximum limit of capacity of the non-rigid was stated to be 500,000 cubic feet. The ability to carry useful load equal to the weight of the ship was expressed as 50 per cent. disposable lift, but disposable lift was something like the League of Nations; it was talked about glibly, but few people knew exactly what it meant. The lecturer showed that it depended upon the difference between the density of the air and hydrogen, and different authorities had different standards for that density. It was estimated at one time as 72.5; in 1914 it was assumed to be 68.6; the French used the figures of 70.14; and Colonel Cave used 64.4. He (Mr. Cole) was taking 68 as the standard representing the actual conditions of airships in this country. The weight of the machinery depended on the horse-power, and that depended on the speed required. The weight of the ship depended greatly on the speed for which it was designed. The maximum speed for the non-rigid shown on the screen was stated to be 50 knots, and the maximum speed for the rigid of the same capacity was 70 knots. If one wanted to make the non-rigid of the size shown on the screen (340,000 cubic feet) up to the 70 knots, the engines would have to be trebled, and the disposable lift, instead of being 35 per cent., would be minus 20 per cent. Any comparison between the rigid and non-rigid on the basis of speed for weight was absurd. The speed of the non-rigid was limited by the fact that the nose went in. As had been shown, it was necessary to stiffen the nose. A speed above 50 knots was not practicable for non-rigids. There was no limit for the rigid, except as to speed for a given horse-power. The lecturer said there was much to be gained by carrying a given weight in several small ships, rather than in one large one. That meant that it was better to carry a large load in several cross-Channel steamers than in a vessel like the "Mauretania," but a big ship was meant to carry a big load. The small airship was in danger of being overtaken by the large aeroplane. There were rigids with a disposable lift of about 58 per cent., and they could travel 70 miles an hour. The Germans had designed one which would have a disposable lift of 80 per cent., but that was an expensive figure. We were only at the beginning of rigid airship design, and there was no factor to limit its development, whereas there was a limit to the size of the non-rigid.

Major J. E. M. PRITCHARD said Colonel Cave seemed to have been led away by his natural enthusiasm for non-rigids into dealing almost entirely with that type, and that the title of his lecture "Lighter-than-Air Craft," not "Non-Rigid Lighter-than-Air Craft," gave the false impression that future airship development would be along the lines of the non-rigid, whereas the rigid would have a far greater future. It was not to be wondered at that Colonel Cave should be unconsciously biased in favour of the non-rigid, as he had been largely responsible for its development, until, at the time of the Armistice, Great Britain had a fleet of the most efficient non-rigid airships in the world. A striking advantage of the rigid was its speed. Out of the six main factors in transport, viz., speed, cost, carrying capacity, regularity, safety and comfort, the claim of aircraft for an

assured future must chiefly be based on speed. The maximum speed for existing non-rigid airships was about 56 miles an hour, against the corresponding speed of 77 miles an hour for rigids. A speed of 90 miles could be confidently predicted in future large rigids, while with non-rigids it was doubtful if a speed of more than 60 miles an hour could ever be obtained.

As the size of an airship increased, the percentage of the gross lift necessary for machinery to obtain a given speed decreased proportionally to the two-third power. The latest type of 2¾ million cubic feet capacity rigids, possessing a disposable lift of 58 per cent. and a speed of 77 miles an hour, had already been compared by Mr. Cole with the corresponding latest type of non-rigid, with a disposable lift of only 35 per cent. and a maximum speed of only 56 miles from the point of view of adding extra machinery to the non-rigid, so that its speed equalled that of the corresponding rigid. If, however, this question of relative efficiency between the rigids and non-rigids were considered from the opposite point of view, and the power units of the rigids were reduced so that their maximum speed were reduced to that of the non-rigids, the disposable lift of the rigid would rise to nearly 70 per cent. against a very problematic 50 per cent. for the future non-rigid.

A rigid equivalent to Colonel Cave's hypothetical 500,000 cubic feet non-rigid would have disposable lift 60 per cent. and speed 90 m.p.h. If the rigid were fitted with smaller power units to develop a speed of only 56 miles an hour (the speed of the non-rigid), a range of some 15,000 miles would be obtained. This range could not be obtained by the 500,000 cubic feet capacity non-rigid, even if the weight of the structure were a minus quantity to the extent of over twice the gross lift of the whole ship. This lack of range was inherent to the non-rigid and to all types of heavier-than-air craft. It was improbable that any heavier-than-air craft would be developed for some years to come which would have a maximum range exceeding 3,000 miles at a speed of, say, 90 m.p.h., and when the range was limited to a commercial range of about one-third the maximum range, the aeroplane and non-rigid became limited to non-stop flights of under 1,000 miles, with the balance of speed in favour of the aeroplane. It was, therefore, for non-stop flights of over 1,000 miles that the larger rigid airship would be supreme.

Major S. HECKSTALL SMITH said he hoped that this was one of the first of many meetings they would have on the subject of airships. We were just on the verge of one of the greatest developments in transport that had ever been dreamed of, and that was transport by airship. It struck him our airship friends were rather like the schoolboy who tried to add a nut to an apple and found the result was a lemon. Why the non-rigid and the rigid should be compared, or why the relative uses of the "Mauretania" and a lot of paddle-boats need be compared he could not understand. Either one would not replace the other. Suppose he had to carry goods across the sandy desert, where an aeroplane could not be used, and the distance was not sufficient to warrant using a 5 million cubic feet or 2½ million cubic feet rigid airship, although the non-rigid could not compete with the rigid, it might easily compete with the camel, both as to speed and disposable lift. It had also been suggested that a useful function of the non-rigid was travelling at night, when gas was not lost, owing to the fact that the temperature was low. Where distances of only 200 or 300 miles had to be travelled, and the ground was impossible for aeroplanes, and there were no railways to compete with, the non-rigid airship might be used, although one would not attempt to use it in flying from South America to the Cape or from the Cape to Australia—which would be a common route for airships in the future. That was especially work for a big rigid. He was glad to see so many engineers present, as there was an immense amount of work for everybody on this problem of the rigid, the non-rigid, and the aeroplane. Each had its own function, and they were not likely to be mixed up. The Hun

had been in front of us on airships and behind us in aeroplanes, and we were now rapidly overtaking him on airships. He had no doubt that, with the engineering knowledge this country possessed, we should go ahead, and he thought that society had done a great work in beginning to open the minds of engineers to the study of this subject. Perhaps they would also be able to open the pockets of the financiers to assist in the matter.

Captain G. S. WALPOLE said he spoke from the point of view of an airship pilot. Heavier-than-air craft had the capacity for long journeys, and for such purposes the only lighter-than-air craft that could compete with them would be the large rigids. There were, however, public duties which could be done by small non-rigids which lay entirely outside the capacity of any aeroplane we now had. He referred to the kind of thing Major Heckstall Smith had outlined —exploring in an island like Tasmania. Only one-third of that island had been surveyed. It was unsurveyable by ordinary means, but with a small non-rigid he thought a fair job could be made of it. The land could be planned out where prospectors could follow and the whole thing could be done in a week, at much less cost than by other means. which would take some years. In a country like this, where agriculture would have to be followed with an intensity we had not dreamed of in the past, the forward nacelle, it might be imagined, would be occupied by a clerk, and the centre by an inspector of agriculture, with, perhaps, an engineer astern. They would set out, say, to survey the agricultural conditions of Kent. Every field would have a number in the corner and when the airship returned that evening there would be a complete survey of the agricultural conditions of the county on that day. Definite instructions could be sent out to certain farmers to use more phosphate, others to improve their drainage, others told they had fly and had to use spray. It took stock riders weeks to count sheep in Australia. A few non-rigids would do that rapidly and well. Wild horses were sometimes turned out and not seen again for three years. The task of finding out where they were before bringing them in could be done by small non-rigids. There would be policed air routes shortly at different altitudes, and he thought the air policeman who stood at the cross-roads and directed the traffic would have some kind of a non-rigid—perhaps one type at 2,000 ft., another at 4,000, another at 10,000, and so on. He hoped to hear more details of the German airships, which had puzzled many peop'e all through the war. He hoped to hear how the large German rigids managed to get to such extraordinary heights and not lose so much lift as to crash on landing. He had thought Colonel Cave would have told them how H. G. Wells's prophecy about men going inside the gasbags of airships to repair leaks, and so on, had actually become a fact. Men actually went inside the gasbags with oxygen apparatus. We would have liked to have heard also something about the success of the wireless. It was extraordinary that it so seldom went wrong.

The CHAIRMAN then invited some remarks from Mr. Gibbon, who, he said, had been for the last 18 months in charge of airship instruction and maintenance in the Admiralty.

Mr. GIBBON said he had been glad to hear several speakers put in a plea for all classes of airships. There were divergent classes required. They all had their functions. Pleasure for all classes and peace amongst their family led to good work and tended to that effort which was what they wanted. One or two speakers had been disappointed that Colonel Cave, with his great knowledge of airship work, had not carried the subject a little further on some points, but he (Mr. Gibbon) had good reason to know that, unfortunately, there was a much-hated person called the Censor, who put certain restrictions on what Colonel Cave was willing to disclose and discuss, and he did not want the blame to rest on Colonel Cave. As Major Heckstall Smith said, the subject was just going to develop, and develop rapidly. If anyone could persuade the financial branch to

take a more liberal and just view of the situation, they would do a great and good work.

The CHAIRMAN said he would like to associate himself with the remarks of the last one or two speakers. There was room for the rigid, the non-rigid, the aeroplane, and the flying boat in the future for commercial purposes. He thought the airship would do the very long distance oversea routes, and that the aeroplane and seaplane would work on the shorter routes both by land and sea. There was a great future for all classes, rigids, non-rigids, and aeroplanes, and it was not a question of one or the other. As regarded the Government assistance, that would be forthcoming, it was difficult to state to-day what that would be, but the question was being given very careful consideration at the present moment. Some very valuable experiments in mooring our airships, water recovery, and long endurance flights would be carried out by the Government. The Government would probably also supply two of the latest airships—Rigid 33 and 34, which had just been produced—for long endurance flights in the Atlantic. They would probably cross to America in the spring when the weather was suitable. Those ships would not compete for the £10,000 prize offered by the "Daily Mail," but when the time came they would show what airships could do in the way of long endurance flights.

Mr. J. R. PANNELL: In the brief space of one evening's lecture Colonel Cave has given us a very complete survey of the general lines upon which airship design is based, but in view of the importance of fundamental principles in obtaining a clear idea of the behaviour of an airship in flight, one feels a little sorry that more time was not devoted to aerostatics. On this point I should like to amplify Colonel Cave's remarks somewhat.

As stated in the paper, the total upward force (or gross lift) on an airship is equal to the weight of air displaced by it. If the gasbags are full the *volume* displaced is practically constant, but owing to changes in the density of the displaced air its *weight* varies. The useful lift is equal to the gross lift minus the weight of the structure and essential parts of the ship, this weight being constant except for changes in the weight of gas or air in the ship.

Consider a rigid airship held near the ground with the gasbags only partly inflated and loaded so that there is a nett upward force. When the ship is released it will rise and the ascent may be divided into two parts, the first during which the gasbag expands and displaces an increasing quantity of air, and the second during which the volume displaced is constant. During the first part, if there is no temperature difference between the gas and the atmosphere and the gasbag is perfectly flexible, the nett upward force will be constant, because the pressure at the bottom of the gasbag is equal to the external air pressure and although the air density is reduced as the altitude is increased the volume displaced is greater in the same proportion. The weight of the ship may be assumed to be constant during this period. When the gasbags are full a further rise causes the atmospheric pressure to fall below that of the gas until the gas valves open when the difference of pressure will remain practically constant again. The weight of the ship will *decrease* slightly as gas is lost, but the effect is small and may be neglected. As the *volume* displaced is constant after the bags are full, the nett lift will fall as the ship rises and the ascent will cease when the weight of air displaced is equal to the weight of the ship. If gas and air temperatures remain equal and the elevators are not used, no further rise will take place unless the weight of the ship is reduced.

Lieutenant-Colonel W. LOCKWOOD MARSH: The question of the basis on which the theoretical lift of an airship should be estimated is a somewhat thorny subject as to which it is extremely important that some definite standard should be agreed upon, internationally, if possible. The German figure of 72 lbs. per 1,000 cubic feet is so hopelessly optimistic in practice that it is most undesirable that it should

be universally adopted as it represents a slightly higher figure than the lift of pure hydrogen. A lift of 68 lbs. represents hydrogen at a purity of 95 per cent. and therefore Mr. Cole's figure is suitable for adoption as the standard for rigid airships, and in fact has been so used in the Naval Air Service for many years. In the case of non-rigids, however, some allowance should be made for the presence of air in the ballonets. Until quite recently this allowance was made by estimating the lift of non-rigids at 64.5 lbs. per 1,000 cubic feet—the figure given by Lieutenant-Colonel Cave-Browne-Cave—which allows of rising to a height of roughly 1,000 feet with losing gas. Latterly there has been a tendency to base the non-rigid estimate at 68 lbs., the same as the rigid. This is very undesirable as in practice an airship pilot will always leave the ground with some air in the ballonets. One would like to suggest that the figures of Mr. Cole and Lieutenant-Colonel Cave-Browne-Cave should be made standard for rigids and non-rigids respectively.

This lecture has brought publicity to an old and regrettable controversy between the rigid and the non-rigid schools of thought. As the Chairman pointed out, there is neither rhyme nor reason for this rivalry any more than for the still worse rivalry between the airship and the aeroplane.

Even supposing, which one does not admit, that Major Pr'tchard is right in limiting the radius of non-rigids to 1,000 miles, there are many countries in the world which are hopelessly unsuitable for aeroplanes, where services of this distance could be carried out by the non-rigid, which is far more economical to build and maintain than the rigid. It is, of course, perfectly obvious that the main aerial trunk routes will employ rigid airships, but there are shorter services —such as that from England to Scandinavia—which are ideal for the non-rigid type. One is inclined to think that for the moment rigid airship designers should concentrate on the design of really big ships—of 5,000,000 cubic feet capacity and upwards—while concurrently attempting to solve the problems of mooring out, superheating, water recovery, etc. This will probably take two or three years, while in the meantime a non-rigid with a circular cross-section envelope of 500,000 cubic feet capacity could be produced quite rapidly and at a comparatively low cost to do the pioneer work in airship transport by starting on the short distance routes in various parts of the world. In this way much valuable data as to the effect of various meteorological phenomena would be obtained, while the way would be paved for the eventual linking up of these non-rigid services by rigids operating on the main trunk routes.

So much work is waiting to be done by both types that it is a pity if the two schools are to waste any of their energies in trying to prove the superiority of their own wares, when each is the best for its own particular purpose—just as the aeroplane and seaplane also have their respective spheres.

Lieutenant-Colonel CAVE-BROWNE-CAVE, replying to the discussion, said he felt very strongly that the development of airships was a work in which very many had shared. He was extremely glad that a considerable number of those who had been concerned in the developments that had been made were present to see how the society appreciated their work.

The first two speakers, who dealt with rigid airships, read into the paper a totally wrong meaning as to the relative position of the rigid and the non-rigid. He was perfectly prepared to admit that so far as carrying large loads and travelling long distances at high speeds were concerned, the rigid had absolute supremacy, but for carrying smaller loads shorter distances, and perhaps at smaller speeds, the non-rigid had a large field. For many naval purposes a non-rigid could be built to fulfil the requirements. The patrols carried out in the North Sea by German Zeppelins could almost all have been carried out by our own North Sea class. The Germans started ahead of us in non-rigid construction, but for some reason they dropped it. The respective limitations of the non-rigid

and the rigid were similar to many engineering questions, such as those connected with the Diesel engine and the turbine. As the size of the Diesel increased the mechanical troubles increased, and the turbine was found more suitable for the higher powers. Above some horse-power the turbine became the best prime mover, but development in the Diesel engine pushed the line of demarcation up, while similar improvements in the turbine pushed it down. The border line between the two varied as it did between the rigid and non-rigid airships.

The step from the 400,000 cubic feet non-rigid, of which they had had long experience, to his hypothetical 500,000 ship was not a very serious one. He made his statements after considering carefully a perfectly definite design. He thought many of the figures and data given by the two speakers who spoke for the rigid were of German origin, and that one might take them with a certain amount of reserve. They were given by German officers and taken from German ships. It reminded him of the lady who said she must have a particular type of car because the *advertisements* spoke so well of it. The speed of the North Sea ship, the design of which was over two years old, was probably not much indication of what one could do with a non-rigid now. It was now possible to devise another shape with less than one-half of the resistance coefficient, so the speed that could be obtained was still a matter of doubt. In reply to Mr. Cole, the conclusions he (Colonel Cave) made were based on the lift of 64.5 lbs. per 1,000 cubic feet of hydrogen, and the reason he took such a low figure was that that in actual practice was about the average lift of the gas in the ships when actually on service. One could design a ship on a lift of 72 lbs. per 1,000 cubic feet, but 64.5 was obtained by making all stations report the purity of their ships on a certain day, and at the time the calculation was made the average purity corresponded to 64.5. He was glad his critics were brave enough to state that they considered the size of the non-rigid limited to 500,000, and the speed limited to 50 knots. It was a more rash statement than he would have made. In reply to Captain Walpole, the German ships did lose lift, and had to pour tons of water out. They got great initial lift from large size and good design. The controversy between rigid and non-rigid was a proper one to conduct before a society like that. He was limited as to the figures and data he was allowed to give, but it was desirable to follow up that controversy and the society would do well to follow his paper with one dealing with the matter from the rigid point of view.

On the motion of the CHAIRMAN, a vote of thanks was accorded to the lecturer, and a vote of thanks was also passed to the Chairman on the motion of Major-General R. M. RUCK (President of the Society), who said he wanted to thank the Admiralty for releasing all the valuable information that had been put before the meeting. The lecture was an epoch-making one, not only because of its intrinsic merit, but because it showed the airship was coming into its own. The Chairman made some allusion to our appreciation of the work done by the personnel of the Air Service. He (General Ruck) was sure no words could express the gratitude they felt as regarded the devotion to their duties and to meeting difficulties which arose. General Maitland was one who in a very marked degree showed devotion to duty, ingenuity and personal bravery.

PROCEEDINGS.

THIRTEENTH MEETING, 54th SESSION.

The Thirteenth Meeting of the Session was held in the Theatre of the Royal Society of Arts, London, on Wednesday, April 9th, 1919, Major-General R. M. Ruck, C.B., C.M.G., R.E., President of the Royal Aeronautical Society, occupying the chair.

The PRESIDENT, in introducing the lecturer, Lieutenant-Colonel H. G. Lyons, F.R.S., said he wanted first to state that that was a special occasion. It was a joint meeting of the two Societies, the Royal Meteorological and the Royal Aeronautical. Before the war they were so much impressed with the necessity for very close co-operation that a Joint Committee was formed and there were one or two joint meetings. It more or less lapsed during the war for a variety of reasons, but quite recently the Royal Meteorological Society asked the Royal Aeronautical Society if they would again co-operate in the same way. They of the Aeronautical Society were very glad to do so, because the war had shown how very necessary that co-operation was. They were fortunate in having Colonel Lyons to lecture to them, an officer who he knew had done so much to bring meteorological information to the assistance of the Air Force. He was sure Colonel Lyons would be able to give them a very interesting communication.

Colonel LYONS prefaced his lecture by saying he could not but feel that he was only repeating perhaps well-known principles, but perhaps that was inevitable in speaking on one's own subject, and he only hoped there might be those present to whom some of the statements he had to make might not be so familiar, and he also hoped they would indulge freely in criticism. The supplier was always anxious to know how his supply was received by those who made use of it. Far too often the user was perhaps too polite to say what he thought. If he would only do so it would be a great gain, not only in the field of meteorology, but in other fields.

Colonel LYONS then delivered his lecture.

DISCUSSION.

Major-General BROOKE POPHAM said the information to be got in France during the war as regarded meteorology was of the greatest possible value. They tried to do without a special meteorological service when the war started, but it was found absolutely necessary to have a local service, and it was started early in 1915, and in a short time the information received from it was quite remarkable for its accuracy, and they could not have done without it. The most important thing from the aviation point of view was that the information had to be got through very quickly. Conditions were somewhat different now from those that prevailed in France. The local meteorological service there only concerned a rather small area of the world. In future the area the service would have to cover was vastly greater, and it might concern—as it did at present—the whole of the Atlantic, the North Sea, and right away to Egypt. He thought that would rather introduce complications, and alter the conditions of the service that would be required. Colonel Lyons said the information was got out at present by maps and particulars that were printed on the maps, but he thought in future they would have to have it by telegram, if it was going to be of real value. In France they had a regular code system. Something like that would have to be evolved for civil aviation. Using a code would reduce the length of the telegram and increase the rapidity with which the information would be got out.

Lieutenant-Colonel A. OGILVIE said the lecture was one of the most stimulating ones to the imagination that he had heard for a long time. The vital point as regarded civil aviation seemed to be the fact that it would depend upon the weather. One could see no serious difficulty in the construction or operation of the machines. They might be a little bit expensive to work at first, but the thing in which it was really difficult to see the complete path open ahead was the meteorological question, and that lecture showed a sort of line of development which was coming. Such difficulties as the weather presented were going to be particularly applicable in this country, where the weather was very bad. That was really an advantage. The weather conditions being very bad, the subject became so serious that one had to get after it and put it right. It was the same with regard to pilots. He remembered Wilbur Wright telling him in 1908 that we should have the best pilots, as our particular conditions were so much worse than those of other countries that our fellows would have to be better than theirs to cope with them. Similarly as regarded the weather, the difficulties would be so great that we should have to develop systems and organisations and study in every way meteorological questions so as to enable us to operate at all. Two difficulties as regarded the weather seemed to be particularly prominent. The first was that of getting the knowledge of the conditions that were coming, such as fog, wind and rain, and the second was the means of overcoming them. Such a lecture as they had just heard did not enable machines to land in fog and rain, and so on, but it helped them to get the knowledge of where the fogs and rain-storms were going to be. The lecturer's remarks about the Nile struck him as being interesting, because some time ago he was messed up with an aeroplane expedition on the Nile, and those particular conditions were forcibly impressed on the minds of those concerned. Their machine did not do 100 miles an hour. Its maximum was quite 60, and it was not a particularly sensitive machine to any kind of weather conditions, and they were particularly sensitive pilots—he thought most of the old pilots were rather nervous and agitated people—and as soon as there were any gusts they used to hurry down. They learnt after a considerable amount of experience that the wind was always blowing in an extremely steady way at certain times of the day. They got perfect flying weather from 7 till 10 in the morning and from about 4.30 in the afternoon until it was dark. The wind during those times was blowing perhaps 30 miles an hour. When they left Wadi Halfa at the beginning of the railway crossing the desert to El Hamid, although it was calm so far as the machine was concerned, it was going in a 30-miles-an-hour wind. Towards 10 o'clock or so the river appeared like a sheet of glass, but a little later, when the sun began to heat the ground, one saw ripples coursing over the surface of the river, and they knew that in half an hour or so those gusts would be coming up their way—they were going along at a modest 2,000 or something like that—and sure enough after a decent interval after seeing those ripples they began to "get the wind up" at the height at which they were flying. On one occasion when they had to carry on till 12 o'clock the weather was horrible and the machine difficult to handle. He wished to emphasise the international nature of meteorological questions. Colonel Lyons had expressed the matter very ably, but he would like to back up everything he had said. Aviation was not a thing one could do by oneself, and he thought it would probably have a very big effect on the whole internationalisation of the world.

Major H. E. WIMPERIS said he must get up to refute the remarks made by the President, in inviting him to speak, that he knew something about the weather. He knew nothing about the weather. That lecture by Colonel Lyons, the honoured head of the chief meteorological service of this country, must interest everyone—everyone, particularly, connected with aviation. There were two sides to meteorological work. The aviator might desire information on the weather for two different purposes. The first was that the best flying routes might be marked out through any part of the world. There were statistical records going back a

long time, available to the statistician, that enable one to ascertain the probable best route between one place and another. The man who examined these statistics was largely a mathematician. The second purpose was of another kind, that was the forecasting side of the thing, which was not concerned in choosing a definite route and landing stages, but the kind of information that would enable one to judge for a half-day, a day—or a week perhaps in future—ahead what the weather was likely to be like at the particular date one proposed to fly along the selected route. That information was much more difficult to obtain. The physics of the atmosphere had to be studied, the temperature pressure, the velocity of the upper wind, the state of the air, and to some extent laboratory experiments based on the friction of fog and wind, and a thousand and one things of that kind. It was necessary to understand the physics of the atmosphere so as to know what was likely to happen on a specific journey. One of the greatest difficulties in connection with this second kind of problem was the difficulty of getting anything like a continuous chain of observations in the upper air. He was afraid no really satisfactory method had yet been got out. A stationary balloon with a meteorological observer attached to it was fascinating from the meteorological point of view, but rather deadly to those who had to fly about a country where there were many of those things about. Mr. Dines had that morning confirmed his opinion that no perfect way had yet been found of getting over this difficulty. Colonel Lyons referred to certain observations in Egypt which seemed to give results that were unexpected, and he drew attention to the need for caution in interpreting the results sometimes put forward. He (Major Wimperis) remembered that when he was at Cambridge Sir Robert Ball, who had made measurements of rainfall for many years, had found his readings were always higher than those of neighbouring stations, but after a number of years it stopped.

Colonel H. T. Tizard said the conditions low down were local, and the air conditions only tended to become such that the meteorologists could deal with them in forecasts at fairly great heights. He could not think it was going to pay for some time for aircraft to fly high. It did not pay from the point of view of fuel, and also navigation was not sufficiently developed. For some time, he thought, flights would mostly be say up to 250 miles and under 5,000 feet in height. Under these conditions in England and a good deal of Europe, one could not forecast with the rapidity and accuracy that would be of any use to aviators. One could only communicate results of observations taken within a reasonably short space of time beforehand, and it seemed the whole secret of the use of meteorology for aircraft during the next year or two was going to be rapid communication. The thing of most importance was to convey results of observations of local weather to aviators a very short time before they wanted to take a journey. From his experience he thought a telegram or the telephone would not be a bit of use in England. He had got tired of waiting for a telephone message from an aerodrome as to the weather there, and had started in a fine patch and got there half an hour after they had sent off a message that flying was impossible. He was convinced that only wireless was feasible, and, that, although there were grave difficulties in the way, they must concentrate on getting some system by which wireless information could be disseminated, if necessary by choosing continuous wave wireless telegraphy for meteorological purposes and keeping other commercial uses to the ordinary wave telegraphy. Meteorological information was of so much importance for other purposes besides aviation that he thought something of that sort was worth going into properly, though it might necessitate disregarding the traditions of the past. Aviators had a chance to help the Meteorological Office by expending a very little extra time and money and supplying them with the kind of information they required. That could not be too much emphasised and could be very easily neglected.

Mr. J. S. Dines said he spoke rather as a member of the Meteorological Office than as representing the Meteorological Society. He was intimately concerned

with the preparation of the reports Colonel Lyons had talked about, and he emphasised how grateful they would be if the users of the reports would give them their opinions and criticisms. They were asked to send reports by telegram and sent them regularly, but did not know whether they were quite what was wanted. If suggestions for their improvement could be made it would be of great service. What Major Wimperis said about kite balloons not being nice for airmen was true. As Colonel Tizard suggested, aeroplanes could take up thermometers and record the temperatures and in some cases get a fairly good idea of the drift of the wind at different levels. He hoped that in future there would be that co-operation, and that the meteorologists would get a great many reports of upper air conditions from aerodromes.

Mr. T. F. GAYNOR asked the lecturer if it would not be an important acquisition to the international meteorological service, especially for Transatlantic aerial navigation in the immediate future, if a few suitably designed station ships were permanently stationed at regularly-spaced distances apart along known parallels of latitude say 40° and 50° north latitude, fully equipped with meteorological instruments and telegraph devices, to observe conditions at their respective localities and report frequently to flying aircraft and to the American and European land stations, and be maintained by the British and American Governments.

Mr. F. H. BRAMWELL asked how much the percentage of accuracy in the forecasts fell off after various periods. A man starting to fly the Atlantic would want to know what chance he had of reasonable Atlantic weather some 20 hours or so after the time he left the ground, or probably more like 30 hours after the forecast was prepared by the Meteorological Office.

Colonel LYONS, replying to the discussion, said with reference to the remark that the war front in France was a small area, the area for which the forecast was supplied was small, but the area from which the material was obtained was not small. It ranged from Iceland to North Scandinavia and down to the Algerian Coast. In Egypt the conditions were simpler and more stable, and the area became more manageable and distinctly smaller. In Egypt, as a rule, dealing with the ordinary weather forecast, and not that supplied primarily for the purposes of aviation, nothing much further off than Malta generally very directly affected them, in less than a couple of days. For use with telephone messages or wireless messages a code was necessary at the Meteorological Office—specially worked out with a view to the simplifying and shortening the transmission of returns and forecasts. When he was in France he was struck with the frequency with which inquiries came in at the Meteorological Office there, and he hoped those concerned in aviation in this country were exercising equal importunity on the offices with which they communicated. He had experienced the strong night winds on the Upper Nile, particularly about the latter part of April, and in May he had experienced them on the desert. Instead of the wind dying down after sunset to a light breeze it remained very strong until well into the early morning. He had never satisfied himself what the reason was. The information given by aviators to the meteorologists had been of the greatest value to the meteorological service in France, and in this country. He had not the figures in his head as to the falling off of the accuracy of forecasts. It was an important point, and should be followed up here and also in other parts of the world. It would naturally vary. Coming back to Egypt, the percentage of accuracy there should be very high for long periods, because conditions were favourable there. He would like to take a particular case in this country, and look that up, and send the inquirer the information. The Meteorological Office would be pleased if fixed stations could be provided on the oceans, but the practical difficulties would probably postpone them for a long time.

The PRESIDENT apologised to Major Wimperis for having accused him of knowing something about the weather. He must have been thinking of the old

saying "He who is weatherwise is no otherwise." The prevailing impression of the lecture upon him was the magnitude which the meteorological service had reached, or would shortly reach. It had evidently grown enormously during the war, and would become a cosmopolitan service, otherwise he gathered from Colonel Lyons that it would be inefficient. He was glad to hear Colonel Lyons say valuable information had been received from the Air Service, because not long ago Sir Napier Shaw, at one of their discussions previous to the war, urged that all the members of the Air Force and all pilots should send as much information as they could, because up to that time they had got very little indeed. We had progressed a good deal since the days of which Colonel Ogilvie spoke, when that frail craft and those two frail pilots—whom other people thought two of the pluckiest pilots that ever stepped—went up the Nile on that memorable expedition, and he did not see now why the weather should affect aircraft very much. In the near future we should certainly have aircraft which would stand anything but the most violent gale. It was, of course, desirable that pilots should know what the air conditions were, and that we should have the highest possible efficiency in the meteorological service. The most perfect organisation was necessary, and it was to the credit of the Meteorological Office that they had advanced so far in that direction. He was sure that the Naval, Military and Air Force were extremely indebted to the Meteorological Office. Colonel Lyons had alluded to the necessity for a central institute. That seemed to him a *sine qua non*, in order to have an efficient administration. He emphasised the necessity of having the co-operation in our own country, but also in foreign countries, of all services that were interested in meteorological information, and he sincerely hoped that by the International Congresses and discussions we were now having some useful means would be discovered of organising such co-operation. He concluded by moving a vote of thanks to Colonel Lyons.

ABSTRACTS.

Curtiss Model K-6 Aircraft Engine.

The Curtiss Model K-6 aircraft engine is of the vertical type, with six cylinders arranged in line; it is rated 150 h.p. at 1,700 r.p.m. The bore is 4.5 in., the stroke 6 in. The cooling is effected by a centrifugal water pump, and lubrication by pressure feed; two high tension magnetos are used for ignition. The engine is fitted with a Duplex type Ball Aero carburettor. It weighs without oil or water 417 lbs., which gives a dead weight per rated horse-power of 2.78 lbs. The gasoline consumption is 0.55 lb. per b.h.p.; the oil consumption, 0.03 lb. per b.h.p.

The installation dimensions are:—Over all length, 63 in.; over all width, $22\frac{3}{4}$ in.; over all depth, $39\frac{1}{4}$ in.; width at bed, $15\frac{3}{4}$ in.; height from bed, $24\frac{1}{8}$ in.; depth from bed, $15\frac{1}{8}$ in.

General Design.—The form of construction adopted in this engine gives a minimum centre distance between cylinders, and this, together with careful placing of the accessories, makes the engine compact and easily placed in the aeroplane body. At the same time the accessibility of the various parts is such that sub-units may be readily inspected or overhauled without disturbing the engine in its mounting on the aeroplane body.

Crankcase.—The crankcase is cast of aluminium alloy with the cylinder water jackets integral; extreme rigidity and absolute alignment of parts are thus maintained, as well as an appreciable saving of lightness gained. The lower half of the crankcase, containing the oil pan, is securely bolted to the flange on the centre line of the crankshaft, which also adds to the stiffness of the assembly.

Cylinders.—The cylinders are rough machined from a special analysis hydraulic steel forging, heat-treated and finish-machined all over, with the cylinder head forged integral.

Bearings.—The crankshaft and connecting rod bearings are reamed, which eliminates the variations that are unavoidable with hand-scraped bearings and permits replacements without fitting, as both the inside and outside diameters of the bearings are made to such fine limits that new ones will drop more accurately in place than would be possible to fit them by hand.

Valve Gear.—The new valve gear used on the Model K6 is a distinct advance over previous engines. A light cam follower relieves the valves of any side strains due to cam action, and provides means of easy adjustment of clearance. As the cam shafts are directly over the valves, all rocker arms, push rods, etc., are done away with and the whole assembly is absolutely oil tight.

Lubrication.—Lubrication is secured by pressure feed through crankshaft, propeller shafts and cam shafts, which insures a continual film of clean oil on all bearings. A separate return pump, with double intake, prevents accumulation of oil in either end of pan, and the consequent flooding of cylinders, when the machine is climbing or gliding. Pressure adjustment permits of individual adequacy of oil feed on each engine and change for wear and varying conditions of service.

A photograph of the engine mounted on a tractor fuselage is given. ("Aviation," February 15, 1919.)

U.S. Navy F-5-L Flying Boat.

The boat is a large patrol craft having a wing span of 103 ft. It was built by the Naval Aircraft Factory. One of its chief features is the armament, which

consists of a Davis Q.F. gun mounted on the bow, nine Lewis guns distributed in such a manner that there is hardly a dead angle of fire to the ship, and a set of triple machine-guns, aft of the engines, which can be swung out through suitable doors whilst the machine is in flight.

Further data are given in the table below:—

Wing span (upper)	103 ft. 9¼ in.
,, ,, (lower)	74 ft. 3⅜ in.
Length over all	49 ft. 3 11/16 in.
Height	18 ft. 9¼ in.
Chord	8 ft.
Gap	8 ft. 10½ in.
Incidence wing	4 deg.
Dihedral	1½ deg.
Draft (full)	27 in.
Total wing area	1,397 sq. ft.
Weight, empty (including water) ...	8,250 lbs.
Useful load	4,750 lbs.
Gross load	13,000 lbs.
Lbs./sq. ft.	9.31 lbs.
Two Liberty motors (12)	800 h.p.
Weight of crew	720 lbs.
Maximum speed	87 m.p.h.
Endurance	7.9 hours.

("Air Service Journal," March 8, 1919.)

80 h.p. Le Rhone Aeroplane Engine.

The 80 h.p. Le Rhone revolving cylinder engine is one of the few pre-war types existent to-day. It has been used extensively at the front for scout and combat duty, but of late principally in observation and bombing machines, notably the twin-engined Caudron biplane. In the United States it has been used in fast solo scouts for advanced training in aerobatics and combat flying, for the Thomas Morse S-4-E, the Standard MEI Scout and other similar planes.

The Union Switch and Signal Co., a Westinghouse concern, were called upon to manufacture the Le Rhone 80 h.p. engine in October, 1917, and the drawings were furnished them at that time.

The engine produced is a copy of the French engine, with changes in some minor details and with materials selected from American sources. The materials have been superior to those of the French, which, together with special treatment, has resulted in practically eliminating engine failures from defective materials. The engine is almost entirely constructed of steel, the only castings being pistons, connecting rod bushings, thrust block liners, and a few accessory parts; there are 32 forgings. The initial weight before machining is 1,160 lbs., the finished weight is 184 lbs., or complete with accessories, 260 lbs.

Continuing, the article gives the advantages of the rotary type engine, together with a brief description of its working principles. The features of the 80 h.p. Le Rhone design are then described with the aid of photographs and the general specifications and performance graph of the engine given. ("Aviation," February 15, 1919.)

Aeronautical Radiators.

The article begins by giving a brief account of the ribbon type radiators, constructed from thin bronze or brass ribbons, at present in general use on aircraft. The author objects to the British honeycomb type with circular tubes, asserting that its ability to cool is not very great and its head resistance is rather

high. (Experiments in Britain have not pointed to such a conclusion.) He recommends the adoption of larger sizes of air passages, because in the case of the smaller sizes the heat dissipated is no greater at high speeds, while the radiators weigh more and present a higher resistance to the air.

A brief indication is given of the method of manufacture.

As regards design in general, the author recommends the enclosure of the engine, where possible, entirely in a streamline housing, excepting exposed valve springs and stems, etc., and putting the radiator by itself in the free air stream. The radiator being especially designed to cool efficiently should be given the whole task of the cooling. In the event of the engine being left entirely or mostly exposed to the air, and located out between the wings, the best location for the radiator will probably be directly in front of the engine. It is good practice to design a rectangular radiator without any tendencies towards irregularities in its outline or cooling section.

A scheme for the preliminary design of radiators is given based on an empirical formula established in the wind tunnel and checked by practice. Having determined the trial size from this information, the radiator should be installed in the machine and the inlet, outlet, and air temperatures observed during best climb. From these observations the necessary modification in size, if any, of the radiator can easily be calculated. The test will be valueless if steam is generated.

A projecting lip around the cooling sections is recommended for small and very narrow radiators, but not for medium size ones, because of the increased resistance. Yawing the radiator increases the cooling capacity, but only at the cost of a prohibitive increase in head resistance.

The upper water tank may act as a distributor and also as a reserve water supply in small machines not intended for long flights; but the reserve tank should be placed elsewhere in large machines. In either case the tank should be streamlined. An excellent position for the reserve water tank is stated to be in the wing. The lower header should act entirely as a collector and should be made as small as possible.

The assigned difference of temperature between water and air should be such as will not allow the water temperature to go above a desired maximum in best climb at the highest air temperature that may be encountered. The density of the air decreases with altitude, the power of the engine varies as the density of the air, but the cooling power of the radiator also varies as the density of the air. Therefore, the only consideration affecting the water temperature, or size of radiator required, is the air temperature (assuming that the percentage of throttle opening remains the same). The value of the temperature difference between water and air should be based on the average highest air temperature at the ground which will be encountered, say 90° F.; and the highest desired water temperature may be taken at 190° F. This gives a difference of 100° F. In all cases of test the air temperature must be taken in flight, and the engine should be thoroughly warmed up before taking off.

The writer strongly objects to the use of nose radiators, owing to the fact that the head resistance due to the radiator is very much greater when the radiator is in the nose than when it is out in the free air stream; and because of the small amount of air flowing through it, it has to be unusually large and heavy. The advantage from the point of view of efficient cooling arising from the low air speed does not outweigh these great disadvantages. An actual test of a British machine showed that the removal of the nose radiator, the streamlining of the nose and the fitting of side radiators, produced an increase of 14 per cent. in rate of climb at 15,000 ft. and an increase of 2½ per cent. in horizontal speed. A retractable radiator is recommended, since shuttering increases head resistance.

With regard to a radiator located in a wing, the author is of the opinion that

there can be no compensation in cooling for the large increase in drag of the wings, and he cites a case of a seaplane in which the top speed after installation of a wing radiator dropped 4½ per cent. at 1,000 ft. and the rate of climb to 3,000 ft. was reduced by 16 per cent. ("Aerial Age Weekly," March 3, 1919.)

New Principle in Carburetion.

The new Brown carburettor is of novel design and is very compact and neat. It is claimed that the correct ratio of air to fuel is maintained automatically at all speeds in either warm or cold weather.

The mixing chamber is spherical, with a fuel nozzle at its lowest point. There is a single intake fitted with a choke valve. Inlet and outlet baffle plates, suitably shaped and perforated, control the proportioning of fuel and air and render it automatic. A petrol bowl beneath the mixing chamber is provided with a float connected to a shut-off valve, so that the depth of petrol can be controlled.

Laboratory and road tests have covered all conditions of motor operation, and the automatic action is uniform under all conditions. Carbon residue, especially on top of pistons and heads, was found to be almost totally absent in the case of a 6-cylinder motor car, weighing 3,475 lbs., after a 78 hours' test on the road. ("Aerial Age Weekly," March 3, 1919.)

Manufacture of Veneer and Plywood.

This article gives a very detailed account of the present state of development of the new plywood industry. There are two distinct manufacturing operations—the cutting of the veneer and the making of the plywood. It is important that the logs to be cut up into veneer should be as fresh as possible, both for ease of cutting and to reduce the possibility of deterioration in the heartwood and along the season checks and cracks.

Rotary cutting, slicing and sawing of the logs are the three possible methods of production of the veneer. The first is responsible for about 70 per cent. of the output. The other two must be resorted to in the case of quartered veneer, where the beauty of the grain is to be preserved. Steaming in bins as a preliminary to cutting is needed for the harder woods, for the thicker veneers, and for wood which is dry or contains frost. The process of steaming takes from 12 to 18 hours according to the pressure of the steam and the nature of the logs.

The rotary cutter is a huge wood-turning lathe with a long stationary knife fixed in position behind the log (which is held between centres), its cutting edge being at the same elevation as the axis of the chuck and spindle. The sheet of veneer comes out at the back of the machine through a slot just below the edge of the long cutting knife. The crew of a rotary cutter consists of five men, one operator, two chippers, and two for steaming and preparation of the logs. The veneer sheets are usually a maximum of 9 feet along the grain and 20 to 30 feet across it.

For sawing and slicing, the logs are quartered and cut into wedge-shaped pieces by means of a large hand-saw. These pieces are trimmed by cutting off the three edges, leaving what is called a "flitch."

The slicer consists of two heavy castings, the stay log to which the flitch is firmly clamped, and the ribbed casting which holds the knife. The stay log has a reciprocating motion forward and downward in the positive direction, and the knife is stationary and slightly inclined upwards. The thickness of the veneer is controlled by the "pressure bar" running parallel to the knife. The veneer is usually not more than 12 to 14 ft. long and 2 ft. wide. Three men form the crew, one to operate the pressure bar, and two helpers to manage the veneer strips.

Veneer sawing is more usual than slicing for quartered veneer, on account of its comparative simplicity; but the saw kerfs lead to more waste than in slicing. The flitch is held by dogs to a heavy stay log which travels back and forth, carrying the flitch against a circular saw. The usual length of the veneer is 14 to 16 ft. and the width 18 to 20 inches. A convenient unit consists of three saws, with a total crew of five men—one expert, two sawyers and two helpers. A band-saw crew of four men will keep the unit supplied with flitches.

After cutting, the veneer is stacked in drying-rooms, where air at 100 to 110° F. is circulated.

In the manufacture of the plywood, jointing and splicing under pressure is usually a necessary preliminary operation in order to get a sufficient width to make up a panel. The inner layers of a panel, being composed of softer and cheaper woods, do not need splicing as they are rotary cut and can be obtained of any width.

Only the inner layers or "crossbands" are put through the gluer, which applies the glue to both surfaces. The core of a 5-ply panel is usually of thicker, poor quality veneer, like chestnut, and this is not put through the gluer. Adjacent plies must have their grain at right angles. The glued panels are placed in piles, 3½ to 4 ft. high, in a hydraulic press and subjected to a pressure of 100 to 300 lbs. per sq. inch for about 5 mins. They are then dried for 72 hours at 70 to 90° F. After cutting to prescribed dimensions and smoothing in a sanding machine, the panels of plywood are ready for issue. ("Aerial Age Weekly," March 3, 1919.)

Experimental Aeronautical Engineering.

In the testing of aeroplanes it is necessary to simulate as nearly as possible the actual stresses which the aeroplane must be capable of withstanding in the severest conditions which it may be expected to have to face, such as in the execution of manœuvres like the loop, steep dive and sharp recovery from a steep dive. In sand tests air and dynamic forces are simulated by the application of loads, which in British and American practice embrace the wings, tail surfaces and controls, the fuselage and the engine mounting. The author describes the lay out, methods and calculations for carrying out these sand tests on the wings, controls and horizontal tail surfaces. The tests employed bring out weak points in the body structure of the various parts and are even more useful in detecting flaws in the attachment of one part to another.

In testing the strengths of materials of the various parts before assembly it is more possible to follow along the lines of ordinary engineering practice, and special machinery is now being developed for the proof testing of struts to the elastic limit with subsequent use on the plane. Rib-testing machines of various types are also being developed.

In testing the performance, controllability, and stability of aeroplanes, both the wind tunnel and actual full flight tests are utilised. In the wind tunnel small accurate models of the type of aeroplane under consideration are subjected to carefully controlled wind pressures and accurate measurements obtained of the stresses and results shown. The author points out, however, that in spite of the great accuracy with which such tests can be made, there is a possibility of error in certain directions, notably in the construction of the models of the identical size and strength ratio to be a true index to the aeroplanes they represent.

In describing the direct methods of testing aeroplanes, the author shows that the only sure way of calibrating the air speed indicator is by flying the plane over a measured two-mile course at a height not exceeding 1,000 ft., and to eliminate the personal equation in testing for stability, methods are being developed by which spring balances attached to the joy-stick measure the exact effort of the pilot under varying conditions of flight, and gadgets indicate the position of the

elevator for various positions of flight. No satisfactory methods have as yet been found for scientifically testing lateral stability or the controllability of aeroplanes, but these problems are being closely investigated. (A. Klemin, "Journal of the Society of Automotive Engineers," March, 1919.)

Line-Reaming Crankshaft Bearings of Liberty Motors.

The Martell aligning reamer was very successfully used on nearly all Liberty engines for reaming the crankshaft bearings. The reaming is done by hand, and the operation was performed in an average time of 30 minutes per motor. The size of holes, alignment and surface of bearings passed the most rigid inspection and tests.

The reamers slip on to a supporting bar and are clamped in position by screws. The bar is supported in two of the crankshaft bearings by plain bushes, and in two further bearings by special eccentric bushes, working in an outer sleeve. By this means perfect alignment of the bar is secured whilst the remaining bearings are being reamed out. The bar is turned by means of a double-end wrench.

The reamers are adjustable and have six blades, of which four are set at a slight left-hand angle, and two at a corresponding right-hand angle.

The expanding mechanism allows of adjustment of the order of 0.0002 or 0.0003 inches. The holes are truly circular to within 0.0001 inch.

The article also describes a fixture for reaming both ends of the connecting rods at one setting. One end of the rod is held in a fixed clamp, whilst the other is gripped by a floating clamp that is securely locked when the smaller reamer, passed through guides in the fixture, locates the up and down position.

The writer considers that the Martell reaming system should find application in the manufacture of all kinds of internal combustion engines in addition to aero-engines.

Two illustrations accompany the article. ("Aerial Age Weekly," March 10, 1919.)

Aeroplane Visibility.

This article, to be concluded later, describes the investigations of the author for the Science and Research Division of the Bureau of Aircraft Production with regard to the various aspects of the visibility of aeroplanes. The paper shows the fundamental data on which the attainment of low visibility for aeroplanes may be founded.

Objects are distinguished through differences in light, shade and colour. To obtain low visibility an object must be similar in colour and distribution of brightness to the background against which it is viewed. Pattern is an essential feature in most cases of successful camouflage, but an exception is when the background is a uniform blue sky. In land and earlier sea camouflage invisibility has been striven for, but in combating short range submarine attack confusibility is found more effectual.

The two general view points of aeroplane camouflage, from above and from below, require camouflage solutions directly contrary to each other. The aspect of the earth surface varies as much with the seasons as does the sky under the varying influence of clear blue or dark or light and bright cloud areas.

The author's first efforts were directed towards measuring the apparent reflection factor of various earth and water areas, the mean hue of earth and water areas, the size and shape of pattern for aeroplane camouflage, and certain brightness measurements in terms of the brightnesses of the sky and of clouds.

The relation of sunlight to skylight is theoretically considered. This matter is discussed very thoroughly and is explained by means of a number of diagrams.

The relative brightnesses or apparent reflection factor of various types of earth areas is dealt with, and a mean equal percentage of 6.8 is given for fields and inland water, with 1.3 for barren land and 4.3 for woods. These figures relate to the late summer, when the landscape was still predominantly green.

Grass plots, like velvet, intermixed with corn fields, ploughed land and woods, provide light traps and shadows so that the mean brightness or apparent reflection factor is materially reduced. If the brightness of the sky $= B$, the brightness of a white horizontal surface $= B$ due to skylight and $5B$ due to sunlight and skylight together. If the reflection factor of a blade of grass $= 0.16$, the brightness of the blades of grass receiving both sunlight and skylight $= 5B \times 0.16 = 0.8B$. The brightness of grass in shadow, if it receives full skylight (this is not practical), $= 0.16B$, so that the mean brightness $= \frac{1}{2}(0.8 + 0.16B)$, and the mean apparent reflection factor would $= 0.48B/5B =$ about 0.1.

Sunlit clouds are often several times brighter than an adjacent patch of blue sky. Dense clouds sunlit are commonly 5 to 10 times as bright as blue sky. Cumulus clouds are a screen as often as a background for aeroplanes, but cirrus clouds, owing to their great altitude, are usually background. Haze in general tends to lower visibility, and the author shows the results of his attempts to obtain the order of magnitude of the luminosity of low-lying dust haze. Water is of little importance in the ord'nary landscape, but is interesting as a background for seaplanes. The mean apparent reflection factor obtained by measurements perpendicular to its surface was 0.068, and most of the measurements were near the mean value. Clear deep water gave the lowest reflection values, which increased very rapidly for shallow water and water containing much suspended matter. (M. Luckiesh, "Journal of the Franklin Institute," March, 1919.)

Future of Aeronautics.

In America a great volume of business awaits the aeronautic manufacturer whose products will satisfy the demands of the critical public interested in sport and commercial aerial transportation. A definite policy must be laid down, and energetic action taken immediately. The absence of information regarding Government policy towards aerial transport is already causing the industry grave embarrassment. It is acknowledged that for some years the industry will require the aid of the State, financially and otherwise, and it is imperative that this be promptly given, before the existing technical staff (both Air Service and Civilian) is dispersed, and absorbed in other industries.

The Aeronautic Convention, to be held at Atlantic City from May 1 to June 1 next, is the industry's best asset. Governments of all Allied and Latin-American countries and their aeronautic, scientific and industrial organisations are invited to attend. The convention aims to permit thorough discussion of all phases of aeronautics, so that those interested in any branch may acquire all the information available on the subject. The subjects for discussion include:—The Large Dirigible and its Value for Transportation; Aerial Mail Plans; Need of Municipal Aerodromes; Aerial Navigation Instruments; Aerial Exploration; Use of Aircraft for Survey; Insurance, Jurisprudence, etc.; Meteorology.

Aerial mail service was inaugurated between Washington and New York on May 15, 1918, and during the first six months its operations covered 68,892 miles at a cost of $75,165.94, including 6 per cent. on investment and 33⅓ per cent. for depreciation. In that period it carried 7,452½ lbs. of aeroplane mail. The revenue derived was $60,653.28. The net deficit, not taking into account the 6 per cent. interest on investment, was $8,969.08. In addition to the aeroplane mail, there was dispatched between Washington, Philadelphia and New York, in the six months, a total of 91,926½ lbs. of first class mail, totalling 3,667,040 letters. This mail was advanced in dispatch from 6 to 12 hours, which many times made up for the small deficit in operating this service.

The service, when operated by civilian flyers of the Post Office Department,

far exceeded the record of its operation whilst under military control, the civilian flyers having a record of only seven forced landings in 100 consecutive flights, and only two failures in that time owing to weather conditions.

The greater the distance between the points on an aerial mail route the greater the saving of time, and therefore the greater the patronage extended by the public to it. It is hoped to establish an aerial mail route from New York to Chicago, and to extend it westward to the foot of the Rockies during the coming fiscal year, with a view to reaching Seattle and San Francisco. This line would be tapped by lines from various other important cities, and another trunk line running north and south and tapped likewise would link up the whole country by aerial mail. The two trunk lines are estimated to cost $1,600,000 and the essential feeders about $400,000 more. Many of these routes have already been reconnoitred, hangars ordered and army aeroplanes earmarked for the service.

Negotiations are in progress for aerial services to the West Indies, Canada, Central and South America.

With regard to the aerial programmes of other countries, Italy has eleven aerial mail lines working or planned; France, six; Great Britain, one—to Paris; Greece, two; Denmark, three; Austria, one; Norway, four; Spain, two. Some of these form parts of the numerous international aerial routes already being planned. A map is given showing the world's air routes as outlined by Mr. Holt Thomas.

A new super-Zeppelin for the trans-Atlantic service is now under construction. It is over 800 ft. in length, has gas capacity of 100,000 cubic metres, nine engines, eight propellers, and will carry 100 passengers, 45 tons of mail and baggage, and 30 tons of fuel, water, and provisions.

The first machine for trans-Atlantic service is to be complete in July. The service will have eight active machines and four in reserve.

For the Roosevelt Arctic Expedition one large seaplane and some smaller planes, based on a ship at Etah, will be used. The expedition will start in June next, and very valuable results are anticipated.

A British Expedition equipped with aeroplanes is due to start for the North Pole in April.

The Aerial Transportation Committee (America), with about 100 members, has been formed to co-operate with the Post Office and City representatives in establishing and extending the aerial mail services. Preliminary reports on the subject of aerial transportation and regulations to govern same have been made, and data has been collected showing the aerial plans of other countries.

President Hawley, of the Aero Club of America, recommends the formation of a Government organisation, capitalised at $50,000,000, to take over the $800,000,000 worth of aeroplanes, motors, and equipment, which the army and navy are trying to dispose of. This equipment and the 20 aviation stations and depots abandoned by the army are to be used for the aerial transportation service outlined above.

The British Air Ministry have sanctioned the scheme to carry foodstuffs to Belgium by aeroplane. Service pilots will be employed, and "the load carried will comprise about two tons of foodstuffs."

The article concludes with a mention of the popularity of the flying boat. ("Aerial Age Weekly," March 17, 1919.)

Aerial Transport.

The "Goliath" machine is an adaptation of the most recent Henry Farman bomber for the transport of passengers. The cigar-shaped nacelle forms a saloon carriage entirely enclosed and provided with glass sides, so that the compartment is well lighted, and yet the draught felt by the occupants is much less than in an ordinary tramcar. It is possible for the passengers to converse easily. There are at present only 15 places, but the machine could carry 30 persons if the nacelle

were made more suitable for their comfort. It is claimed that the machine is very steady, and also stable in flight.

The principal dimensions of the Goliath are as under:—

Span	92 ft.
Wing surface	1,780 sq. ft.
Total weight	11,000 lbs.
Useful load	6,600 lbs.

Two 270 h.p. Salmson motors.
Speed, 104 m.p.h.

Farman has not reckoned upon running the motors at full power, which would enable an extra 1,100 lbs. of useful load to be carried. Its normal speed of flight is 94 m.p.h.

The machine will fly well with half load if one engine gives out. A forced landing due to failure of one engine when full load is being carried could be carried out very slowly. The author points out that the useful load of the Goliath is half as much again per horse-power as that of the Handley Page.

Possible means of determining latitude during long voyages are discussed; also the advisability of providing luminous buoys as an indication of position over the sea. The writer asserts that the compass should always be placed at least 11 feet from large masses of metal.

The article concludes with a comparison of the cost of transport by various means of one tonne for one kilometre. The figures are as follows:—

Vehicle.	H.P. for one tonne per kilometre.	Cost of fuel and oil per h.p. hour in centimes.	Relative total costs.
Steamboat	1/75	8	1
Railway train ...	1/22	10	4.25
Automobile	1	—	—
Aeroplane	1	40	375

In spite of the formidable difference in price between transport by aircraft and by train or boat, it appears that there is no reason why aircraft should not become as largely useful in a different way as the automobile now is. The fare per kilometre by air should not be appreciably greater in the near future than it is now for travelling first class by rail. (E. Archdeacon, "L'Aérophile," February 1-15, 1919.)

Commercial Aviation.

This article gives an estimate of the cost of maintaining a service of ten large Caudron aeroplanes, with two reserve machines. The calculations are based upon war experience, and the resultant cost may, therefore, be very excessive; for war machines are not designed primarily for economy of cost. The small scout machine is ruled out as being far too expensive, and the largest type is chosen for the calculations, although a medium-sized machine with higher speed may possibly be more economical.

A tabular statement of costs is given at the end of the article, and the fare per passenger to give a profit of 10 per cent. is estimated at 90 centimes per kilometre, or about 1s. 2½d. a mile. (Capt. E. Riche, "L'Aérophile," February 1-15, 1919.)

First French Trials in Aerial Transport.

In this article brief accounts are given of the flights of the "Goliath" from Paris to London and back, and from Paris to Brussels and back; also the voyage of the Caudron C.23 to Brussels and back.

The Goliath carried 14 persons to London in 2½ hours, the landing being

made at Kenley, near Croydon. The return to Paris was accomplished in 3 hours 10 minutes.

A further note describes the crossing of the Mediterranean at its widest point by two French aviators in a 300 h.p. Breguet machine. The return journey was made on the same day, and in spite of exceedingly bad weather. 900 miles were covered in 10 hours 35 minutes. ("L'Aérophile," February 1-15, 1919.)

Spanish Air Service to America.

The Compañia Transatlantica is preparing to undertake a passenger aerial service between Spain and America, on the lines suggested by the Major of Engineers D. Emilio Herrera. The company has appointed a Commission, consisting of Major Herrera, who is Director of the Central Meteorological Observatory, and Colonel Galbis, of the General Staff, who will leave at an early date for Paris, London and Scotland to study the construction of the large airships which are being built in those countries. ("España Economica y Financiera," March 29, 1919.)

Goodyear Airship Type.

The Goodyear Tyre and Rubber Co. during the war constructed military airships, varying in size from 75,000 cu. ft. to 170,000 cu. ft. capacity, the overall length of the biggest ship being slightly under 200 ft.

An illustration is given of an airship of 95,000 cu. ft. capacity. The length of the gas bag is 162 ft., the diameter at the greatest cross-section being 33 ft. 6 in. The car is 18 ft. long and is equipped with a 150 h.p. Thomas engine. Seating capacity is provided for six, but the regular crew generally consists of three or four. The ship was designed to have a cruising radius of approximately 12 hours at full throttle and a speed of 56 m.p.h. with full load.

When flying over water, arrangement is made to take in ballast by a hose pipe to replace loss of weight due to fuel consumption. The longitudinal balance of the airship is controlled by shifting air in the ballonets.

The air valves are located on this particular ship in the ballonet, and are about 18 in. in diameter. These valves are set to operate at a pressure of 1.5 ins. of water, and weigh approximately 16 lbs. each.

The suspension of the car to the gas bag is of the finger patch type, by means of which the stresses are satisfactorily transferred to the fabric.

The blower arrangement for forcing air into the ballonets consists of a small Sturtevant fan driven by an electric motor. During regular flying the air scoop takes care of all necessary ballonet requirements and, consequently, the blower is used very seldom. (H. T. Kroft, "Aviation," March 1, 1919.)

American-Built Aeroplanes, Seaplanes and Flying Boats.

The table under this heading gives the following characteristics, etc., for various American machines:—Government department or manufacturer; type; number of crew; number and make of engines; horse-power at r.p.m.; weight of engine (lbs.); weight of radiator and cooling water (lbs.); gross weight (lbs.); weight empty, with water (lbs.); fuel and oil (lbs.); military load (lbs.); crew (lbs.); total wing area incl. ailerons (sq. ft.); power loading (lbs. per h.p.); speed (m.p.h.); level (ft.); climb (min.); ceiling (ft.); span; chord; gap; incidence of wings (deg.); dihedral (deg.); sweepback (deg.); decalage (in.); stagger (deg.); length (ft.); height (ft.); area of stabiliser (sq. ft.); area of elevator (sq. ft.); total aileron area (sq. ft.); area of fin (sq. ft.); area of rudder (sq. ft.); total vertical area (sq. ft.); fuel capacity (gal.); oil capacity (gal.); landing speed (m.p.h.).

The machines are separated into groups:—(1) Small single-seaters, (2) single-seater training machines, (3) single-seater pursuit machines, (4) two-seater training

machines (primary and advanced), (5) two-seater fighter, reconnaissance, or day bomber machines, (6) night bomber machines, (7) training seaplanes (pontoons), (8) light bomber seaplane (pontoons), and (9) submarine patrol and convoy machines (flying boats).

Several gaps appear in the tables, the landing speed column being usually omitted.

The highest speed given is that for the Curtiss single-seater pursuit machine (1,820 lbs. gross weight, 1 Hispano-Suiza, 220 h.p. at 2,150 r.p.m.), viz., 135 m.p.h. at 5,500 ft. and 116 m.p.h. at 20,000 ft. This is also the best climbing machine out of those whose figures are given, climbing 10,000 ft. in 8 min. This machine is closely followed by the Packard-Lepere two-seater fighter, etc. (3,745 lbs. gross weight, 1 Liberty 12A, 597 h.p. at 1,700 r.p.m.), which travels at 130 m.p.h. at 5,000 ft. and 94 at 20,000 and climbs 10,000 ft. in 9 mins. 50 secs. The landing speed is not given in either case.

The ceiling for the former machine is 22,300 ft. and for the latter 20,200 ft. The highest figure given is 23,000 for the Loening two-seater fighter (2,360 lbs. gross weight, 1 Hispano-Suiza—H, 340 h.p. at 1,800 r.p.m.), and also for U.S.A. Bristol (2,910 lbs., 1 Hispano-Suiza, 310 h.p.). ("Aviation," March 1, 1919.)

W.K.F. Battle Triplane.

One of the most noteworthy types of aeroplanes introduced during the war is the single-seater battle triplane. It is the result of an endeavour to increase the climbing speed and hence the fighting qualities of the biplane. It has the disadvantage, however, of decreasing the range of vision of the pilot.

Two diagrams are given showing the W.K.F. triplane designed by A. Gassner. The necessity for a blind spot as small as possible, combined with the distance between the planes and the size of the 200 h.p. motor, gave rise to a deep narrow body which was streamlined and rounded off. Investigations were also made with rectangular and circular bodies, the latter being discarded on account of instability and the former because it interfered too much with the lower plane and its resistance was higher.

Ailerons are fitted to the two upper planes, those on the midd'e plane being controlled directly and the upper ones coupled to the lower ones. The elevator and rudder are of normal construction. The landing gear and skid are exceptionally strong and sprung with spiral springs.

The 200 h.p. motor consumes about 225 grs. of fuel per min., which allows a 1½ hour flight with a fuel capacity of 100 litres. The radiator is small, and is attached to the leading edge of the top wing in such a way as not to decrease the pilot's field of vision. The boss of the four-bladed airscrew is faired.

A table is given showing the weights of the component parts of the machine in detail. The weight of the machine, empty, is 670 kilos. The body weighs 44, the landing gear 41, the motor 308, and the radiator 25 kilos. 155 kilos are allowed for the pilot, armament, and ammunition, 70 for fuel, 15 for oil, and 25 for water, making the total weight 935 kilos.

The area of the planes is as follows:—

Top plane	...	...	...	...	9.06 sq. metres.
Middle plane	...	...	...	...	5.96 ,, ,,
Lower plane	...	...	...	...	7.47 ,, ,,

(F. Schieferl, "Oesterreichische Flug-Zeitschrift," February, 1919.)

Packard Aeroplane.

Power Plant.

Packard 8-cyl., 160 h.p. engine; 160 h.p. at 1,525 r.p.m.

Weight, complete with propeller hub, self-starter, battery, and engine water, 585 lbs.

Fuel consumption, 0.50 to 0.54 lb. per h.p. at sea level.

Wing and Control Surface Areas.

Main planes, total	387.6 sq. ft.
Ailerons, total	48.3 ,,
Vertical fin	7.0 ,,
Rudder	12.0 ,,
Tail plane	35.7 ,,
Elevator, total	21.9 ,,

Weight.

Machine empty	1,520 lbs.
Gasoline	210 ,,
Oil	30 ,,
Water	52 ,,
Tools and extras	25 ,,
Pilot	165 ,,
Passenger	165 ,,
Normal flying weight	2,167 ,,
Weight, lb. per h.p.	13.5 ,,
Wing loading per sq. ft.	5.6 ,,
Permissible extra luggage	100 ,,

Performance (Estimated).

High speed near sea level	102 m.p.h.
High speed at 5,000 ft.	100.5 ,,
High speed at 10,000 ft.	98 ,,
High speed at 15,000 ft.	90.5 ,,
Climb to 5,000 ft.	7.5 min.
Climb to 10,000 ft....	18.1 ,,
Climb to 15,000 ft....	34.5 ,,
Absolute ceiling	19,500 ft.
Fuel range, wide open near sea level ...	2.5 hr.
Fuel range, wide open at 5,000 ft. ...	3 ,,
Fuel range, wide open at 10,000 ft. ...	3.5 ,,
Fuel range, wide open at 15,000 ft. ...	4 ,,

("Aviation," March 1, 1919.)

Packard Aircraft Engines.

Three engines are described, but as they are of similar design the following description of the smallest design, model 1-A-744, aptly describes the entire line:—

Number of Cylinders.—Eight, $4\frac{3}{4}$ in. bore by $5\frac{1}{4}$ in. stroke—set at an included angle of 60 deg.

Crankshaft is of the 5-bearing type.

Connecting rods are of the straddle type.

Pistons are of the aluminium die-cast type, equipped with floating piston pin, and a new arrangement of rings to prevent fouling of plugs when coasting down from high altitude.

Propeller Hub is of the quick detachable type, carefully designed to prevent freezing on the shaft or becoming loose.

Crankcase is of box section type, split on the centre line of the crankshaft with the main bearings carried between.

Cylinders are of the individual steel type.

Valves are 2 in. diameter in the clear, with 30 deg. seats, the intake valve lift being 7/16 in. and the exhaust $\frac{3}{8}$ in.

Camshaft and Rocker Arm assembly is of the enclosed type.

Lubrication is of the full pressure feed type. The oil pump, screen, and blow-off valve are located low down.

Cooling System.—The engine is designed especially for the use of a nose radiator, but is equally adaptable to any other type of radiator arrangement.

Ignition is an improved Delco type, in which the heads remain stationary and the spark advance is obtained by advancing the drive shaft.

Carburetion.—The carburettor is of the double Venturi type, with improved altitude adjustment.

Weight.—The engine, complete, with propeller hub, carburettor, ignition distributor heads, ignition switch, generator, starting motor and starting switch, weighs 520 lbs. A proper battery to provide current for cranking and starting ignition weighs 40 lbs. The water contained in the cylinder jackets, pump and pipes weighs 25 lbs. A nose radiator to cool this engine holds 27 lbs. of water, making the total weight of cooling water 52 lbs. A nose-type tubular radiator weighs 73 lbs.

General Dimensions.—Centre to centre of bed timber bolts, 14½ in.; extreme width over-all, 27½ in.; highest point above bed timber, 20½ in.; necessary distance between radiator and front bulkhead for proper mounting is 34 in. to 36 in. ("Aviation," March 1, 1919.)

King 550 h.p. Aircraft Engine.

The King 550 h.p. aircraft engine is largely constructed of aluminium, the main casting, the ribless slipper pistons, the removable cylinder heads, and the removable cylinder liners, which have cast iron liners of 0.0627 in. wall thickness, being all made of aluminium. Each cylinder head is fitted with a removable cover to allow the clearance between the rocker arms and valves to be adjusted. The connecting rods are of the articulated type, in which the smaller or articulated rod, big end bearing, is carried by the master rod. The wrist pin of the piston is of the floating type, with aluminium end plugs. The crankshaft is of the six-throw 120° type, and the main crankshaft bearings are eight in number. A special King designed carburettor is used with one common float chamber. The lubrication system gives a pressure feed to all bearings, the normal pressure being about 45 lbs./sq. in.

The other and main characteristics of the engine may be briefly summarised as follows:—

Twelve cylinders, fixed, water-cooled; six cylinders arranged in each bank of a 45 deg. V.
Bore, 5.5 in., 140 mm.
Stroke, 7 in., 178 mm.
Engine displacement, 1995 cu. in.
Rated h.p., 550 at 1,886 engine r.p.m., 1,300 propeller r.p.m.
Ignition, two independent magneto systems.
Inlet cam lift, 0.396 in.
Inlet valve lift, 19/32 in.
Inlet valve seat angle, 10°.
Inlet valve lift area, 5.51 sq. in.
Inlet gas velocity, 9,500 ft.-min.
Each (2) exhaust cam lift, 0.334.
Each (2) exhaust valve lift, ½ in.
Each (2) exhaust valve seat angle, 30°.
Each (2) exhaust valve lift area, 5.625 sq. in.
Exhaust gas velocity, 9.300 ft.-min. ("Aviation," April 1, 1919.)

Lawrence 3-Cylinder Aeroplane Engine.

The performance curve shows that this engine develops 41.5 h.p. at 1,200 r.p.m., 47 h.p. at 1,400 r.p.m., and 52.5 h.p. at 1,600 r.p.m. The bore is 4.25 in., the stroke 5.25 in.

The crankcase and air-cooled cylinders are of aluminium. The crankcase contains a single-throw crankshaft of chrome nickel steel, on which the three

connecting rods work, and the reciprocating and rotary forces are counter-balanced by a pair of balance weights. This gives a very good balance, far superior to the four-cylinder automobile type of engine.

The cylinders are of cast aluminium with air-cooling fins machined on them, and with the head integral with the cylinder. In the head is cast a bronze seat for valves.

The valves, one inlet and one exhaust, are mounted in the head at a slight angle with the bore. The valve springs are of a new type. They are made of a flat ribbon of steel, which is tapered so that its width is considerably less at one end than at the other. It is then rolled into a spiral, the wide part of the ribbon forming the outer coils. This gives a spring which has a very short over-all length, and in which all the coils are stressed equally.

The steel liners are pressed into the cylinder by a hydraulic press. They are 1/16 in. thick, and case hardened and ground in place. The pistons are of the ordinary round type with flat heads, and they have four ⅛ in. rings at top and one wiper ring at the bottom of the skirt.

The wrist pins are of the full floating type. The connecting small end is bushed with Non-Gran bronze, and the rod itself is a hollow round rod drilled from the top end. The big end of the rod is in the form of a segment of a circle, and fits in two grooves in the bronze bearing on the crankpin. The crankshaft is made all in one piece, and the same bronze bushing is slit and bolted together with four bolts.

The valves are operated by means of three individual camshafts, one for each cylinder, which are also used to drive various auxiliaries, such as oil pump, distributor, tachometer. On account of the expansion of the cylinder, the valve clearance varies very considerably, and the camshafts are so designed that the rollers attack the cams for the proper timing with 0.060 in. clearance.

The oiling system is interesting, in that the manufacturer employs a system whereby the crankpin is oil cooled.

Two forms of ignition are used on these engines, namely, a special magneto, which was designed for this engine by Mr. Kliesrath, the engineer of the Simms Magneto Co., or the Philbrin battery ignition. Both these systems are of interest, as in both cases two plugs are fired absolutely simultaneously, only one breaker being used at a time. The high speed of the magneto makes starting easy, and the magneto can be reduced to the smallest possible proportions, weighing in this case 7½ lbs. The Philbrin ignition runs at one-half the engine speed and consists of two separate primary breakers, two high tension distributors, and two coils. The weight of the motor is 130 pounds with magneto and 132 pounds with the Philbrin system.

The carburettor used is a Miller 1¾ in. type, with barrel throttle having an altitude adjustment by which the level in the float chamber can be varied to suit the conditions. ("Aviation," March 1, 1919.)

Thomas-Morse Model 8-90 Aero Engine.

Type: 8-cylinder "V," four cycle, water cooled, dual ignition; cylinders, 4-13/16 inches bore by 6 inches stroke; b.h.p., 250; r.p.m. of engine, 2,200; r.p.m. of propeller, 1,512; consumption of petrol and oil, 0.54 and 0.04 lbs. per h.p. hour respectively.

Weight complete with propeller hub, flanges, and bolts, but excluding radiator, water, oil, starting device, exhaust pipes, and propeller, approximately 590 lbs.

The special aluminium alloy cylinders are of the "L" head type and are cast in blocks of four with integral water jackets. The cylinder heads are bolted on and cast iron liners are fitted.

The Tungsten steel valves are made in one piece, and have a part opening of 2-13/16 in. The valve push rods are operated directly by the cams, and are adjustable.

The three-bearing hollow camshaft is located in the crankcase. The timing gear is bolted to the driven end of the camshaft, which is flanged for this purpose. Lubrication is provided by overflow through the pressure-regulating relief valve.

The crankshaft, made of special chrome nickel steel, is carried on three bearings. The journals and crank pins are 2½ in. in diameter, drilled for lightness. Oil is led to the connecting rod big ends through ducts drilled in the crank webs.

The connecting rods are of H section. They are made of chrome nickel steel, and are arranged side by side on the same crank pin for opposite cylinders. The wrist pins are locked in the connecting rods.

The pistons are made of special aluminium alloy, and are provided with two concentric lap jointed compression rings near the head, and one oil scraper in the skirt.

The crankcase is a special aluminium alloy casting; the lower half, which serves only as an oil sump, is bolted directly to the upper half.

A Stromberg, double vertical carburettor is used. The double branch manifold is an aluminium casting and is water-jacketed.

The lubricating system is of the high pressure circulating type. The pump is provided with a fine wire mesh screen. The wrist pins and pistons, cams and push rods, are lubricated by the oil thrown off the crank pins; whilst the reduction gears are constantly sprayed with a stream of oil from the main oil duct. All surplus oil collecting in either end of the oil pan is drawn off by a second oil pump, filtered, and delivered back to the supply tank.

The cooling water is supplied by a single centrifugal pump driven at camshaft speed. Water outlets are arranged over each exhaust valve.

The propeller shaft is of large diameter and drilled for lightness. It is driven from the crankshaft through two chrome nickel spur gears, and is supported on three ball bearings housed in an aluminium alloy gear case.

Two Splitdorf "Dixie" magnetos are used, with two sparking plugs per cylinder. Provision has been made to allow the use of "Dixie 84" magnetos with adjustable spark, or fixed spark "Dixie 810" magnetos and hand starting magnetos.

The Christensen air starting system can be used on this engine if desired. A gravity fed petrol gear pump is supplied as a regular part of the equipment, and a tachometer is also provided.

Two illustrations of the engine accompany the article. ("Aerial Age Weekly," March 10, 1919.)

Murray-Willat Valveless Rotary Engine.

The Murray-Willat valveless rotary engine is of the two-stroke type, with a pressure blower built as an integral part, which compresses the air and forces the fuel into the engine at altitudes where the rarefied atmosphere fails to perform this function.

	35 *h.p. model.*	90 *h.p. model.*
Bore	75 mm.	100 mm.
Stroke	90 mm.	130 mm.
Engine speed	1,200 r.p.m.	1,200 r.p.m.
Horse-power	35	90
Gasoline consumption	14 litres p.h.	24 litres p.h.
Oil (mineral) consumption ...	6 ,, ,,	10 ,, ,,
Maximum diameter	660 mm.	737 mm.
Weight, including airscrew hub...	60 kg.	118 kg.

The cylinders are turned from forged steel billets. The crankcase consists of two halves which are machined from solid steel forgings.

The connecting rods are mounted in a spool which is carried in a ball bearing on each end, the whole unit revolving with the engine, while the crankshaft

remains stationary. The latter is hollowed out for the purpose of affording passage to the gas from the blower into the crankcase, where it is held under a pressure of 7 lbs. per sq. in. furnished by the blower. ("Aviation," March 1, 1919.)

Liberty Aircraft Engine Ignition.

The reliability of all high-powered aeronautical engines in flight is largely governed by the dependability of its sparking plugs. The service, due to the extreme temperature and pressure conditions, is so severe that satisfactory performance can only be obtained by the use of duplicate sparking plugs in each cylinder. This design requires the use of an ignition system so duplicated that independent operation can be obtained with either set.

The Delco generator battery type of ignition, having proved itself particularly adapted for reliable high speed work, is used as the means of operating all Liberty aircraft engines. The Liberty ignition produces a spark of maximum intensity at low speed, ensuring easy starting and regular idling. It consists of a constant source of low voltage direct current, supplied by a generator and a storage battery. The generator is so arranged that the voltage is kept constant at all operating speeds. As the generator does not produce sufficient voltage at cranking or extreme low idling speeds, the current at this time is supplied by the battery. In this way a particularly constant pressure of low voltage current is available at all times. Above speeds of 650 r.p.m. double ignition is used, at which time the generator is automatically placed in the circuit, and supplies the current for the ignition and keeps the battery charged.

The low voltage current supplied by the battery or generator is controlled by means of a two-lever switch unit containing an ammeter which at all times indicates the flow of current to or from the battery. Through the switch the current is supplied to the distributors, which are mounted horizontally and form the ends of the overhead camshaft housings. The distributors, which are identical and interchangeable, are constructed with an ignition coil, which provides the means of transforming the low voltage current to high voltage, and a breaker mechanism. The high tension current generated in the secondary winding of the coil is delivered to a high tension rotor fastened to the cam actuating the breaker mechanism contact arms, and distributes the high tension current to the spark plug lead terminals. Advance and retard is obtained by revolving the distributor breaker mechanism and head on its base. A retard of 10 deg. and an advance of 30 deg. is provided.

Ammeter.—The use of an ammeter permanently located in the primary circuit gives a very rapid method of checking the condition of the entire low voltage circuits; this can be done with engine stopped or operating; not only proper ignition performance, but improper functioning, even though the engine may be running regularly, is immediately indicated and can be rapidly isolated.

Generator.—The generator is a four-pole shunt-wound unit of compact design and of the rugged construction which low voltage direct current machines permit. It is approximately 8½ in. high and 4¾ in. in diameter, and weighs 11.25 lbs., and is driven at one and one-half times crankshaft speed. It is made up with a forged steel field frame and provided with four forged pole pieces securely held in place by two shoulder tap screws each. The field coils are wound and connected together, properly shaped, impregnated with insulating varnish, and rigidly held in place by the pole pieces. The upper housing contains the four brushes (*i.e.*, two positive, which are insulated, and two negative, which are grounded direct to the frame).

The shunt field obtains its current by being directly connected to the armature circuit in the generator. The voltage is controlled by the current flowing through the field, which is automatically governed by the regulator. The armature, which has twenty-one slots, is of the wave-wound type with formed coils well insulated

and secured in the core slots, and held in position by banding wires. The commutator is built up of hard-rolled copper and contains twenty-one segments with mica insulation. After the armature is completely assembled, it is impregnated with heat-resisting insulating varnish and baked.

The voltage of the current furnished by the generator is that governed by a voltage regulator, so that it never exceeds 10 to 10½ volts. Its current output is governed by the battery condition and load, but the generator is arranged to carry 5 to 6 ampere load continuously without excessive loading.

Voltage Regulator.—The regulator is an automatic device, controlling the amount of current flowing through the generator field circuit. In design it consists of a soft iron core, over which is mounted a pivoted iron armature, normally held away from the core by an adjustable coil spring in tension. Mounted on this armature is an adjustable tungsten contact point in circuit when closed, with a stationary contact, and forming a generator field connection to ground of low resistance. Around the core are wound three windings, which control the opening and closing of the contacts and the current in the generator field circuit.

The voltage generated in the generature armature is impressed upon a voltage winding, and as the speed of the armature or the strength of the generator field increases, the amount of current flowing through this winding increases, producing an increasing amount of magnetism in the core, and attracting the pivoted armature which causes the contacts to open. This immediately reduces the current flowing in the generator field to the amount limited by the flow through the other two windings, causing a weakening of the generator field and a corresponding control of voltage. The decrease in magnetic attraction of the voltage coil permits the spring to again close the contacts, and establish a low resistance field path to ground. This action is repeated very rapidly causing the contacts to continually vibrate at high speed, increasing as the speed of the generator armature increases.

The regulator is adjusted by changes of spring tension. Increasing the tension increases the voltage produced by the generator, and *vice versa*.

Distributors.—To supply the duplicate ignition required, two 12 or 8-cylinder distributors are provided, each one furnishing one of the plugs in each cylinder with an ignition spark at the proper time. Each distributor weighs 5.5 lbs. and is $7\frac{3}{4}$ in. over-all diameter and $5\frac{5}{8}$ in. high. They are mounted one on each of the two overhead camshafts, fastening direct to the camshaft housing.

The ignition coil, which is contained in the distributor head, is a device by means of which induction low voltage current is transformed to high voltage current. The high tension terminal of the coil is a carbon button, extending through the under side of the head, and when in position on the breaker mechanism makes contact with a flat spring on the high tension rotor.

The rotor carries a soft carbon brush, which bears upon a hard rubber track. The high tension terminals are spaced at proper angular relation around the periphery of the distributor head rim, the terminals being moulded in the hard rubber track. The primary winding receives its current direct from the switch. The current, after passing through the primary winding, continues to the breaker mechanism, which completes the circuit to ground. Both the battery and generator have their negative side grounded, using the engine frame as negative side of the circuit.

The breaker mechanism consists of contacts operated by a cam, which opens and closes the circuit between the primary winding and ground. Two of the contact arms, located diametrically opposite each other and called the main contacts, interrupt the primary current, producing ignition. A third contact arm, called the auxiliary arm, is electrically in parallel with the main arms, but also in series with a resistance unit, which limits the flow of current to this arm. This forms a safety feature, preventing the engine from operating in a reverse direction. ("Aviation," March 1, 1919.)

ABRIDGMENTS OF RECENT PATENT SPECIFICATIONS (AERONAUTICS).

123,538. C. O. Clementz, Malmo, Sweden. February 9, 1917.

Range Finders.—Apparatus for determining the position of a distant aerial object, comprises a disc rotatable about a vertical axis at a main sighting station, a sighting device rotatable in or parallel to the plane of the disc, an arm rotating about a fixed point in accordance with the azimuth of a sighting device at an auxiliary station, and means for indicating on the disc the point of intersection of the vertical plane containing the arm and the line of sight of the device; means for indicating the speed of the object and other gunnery factors may be provided, and the apparatus at the main station may be duplicated at the auxiliary station. The rotatable disc is mounted on a stand and is graduated by vertical and horizontal lines. A graduated sighting rule having sighting plates, the lower one of which is carried by a piece slidable in the line of sight, is pivoted on the disc at the bottom of the vertical edge about which it rotates. The arm is rotatable above a graduated disc mounted on the said stand or on a separate stand, and is adjusted by hand or electrically from the auxiliary station. The apparatus at the auxiliary station comprises a sighting instrument mounted to turn vertically on a holder rotatable about a vertical axis and carrying a pointer turning over a graduated disc. The apparatus at the main station comprises a vertical ruler which is adjusted automatically by the arm, being connected by a frame to a tube, which slides in a slot in the arm and in a slot beneath the disc. The tube holds a pencil or pen which traces a record of the horizontal movements of the object on a map table. The horizontal speed of the object may be indicated by the provision of a clock which rotates a wheel, having projections which engage one end of a lever and cause its other end to lift the pencil at known time intervals and momentarily interrupt the record. The clock is mounted on a frame carrying a wheel which causes it to trail behind the pencil, and the horizontal speed of the object or the distance passed over in any number of seconds may be indicated on a scale by a pointer. The pointer is carried by a plate pressed into frictional engagement with the wheel for the desired time, it being thus lifted from its lowest—*i.e.*, zero—position to its reading position on the scale, and then being allowed to fall and to be again lifted for another indication. To enable these movements to be effected the plate is connected to another plate, which is normally gripped between a lever and a further plate pressed by a spring. The pencil tube carries a rule which projects in the opposite direction to the frame—*i.e.*, in the direction of travel of the object—and is situated above a plate bearing angular graduations and arcs of equal horizontal range. The correction of the laying of the gun to allow for the time of flight of the shell may be determined by using the reading of its speed to calculate the distance the object travels in this time, and then reading from a corresponding graduation on the rule the angular deviation during this time and its range after the time. Apparatus for transmitting electrically the azimuth readings at the auxiliary sighting station may comprise electro-magnets at the main station which are carried in an annular frame constituted by rings and walls and corresponding contacts at the auxiliary station. The magnets are arranged at varying radial distances to reduce the limits of the angular error in transmission and their cores are connected to upper and lower radial bars. Spokes having ends which are forked so as to pass above and beneath the bars and constitute armatures are carried by an axle carrying, or geared to, the arm. The magnets at the main station and the corresponding contacts at the auxiliary station are connected in circuit, and to obtain a greater

turning power and to reduce the number of wires between the stations several electro-magnets separated by equal angular distances—*e.g.*, every tenth magnet—and the corresponding contact may be connected in series or parallel in the same circuit. The readings at the auxiliary stations may be electrically transmitted to several main stations.

123,539. A. F. S. Kent, 10, Downfield Road, Clifton, Bristol. March 15, 1917.

Respiratory Apparatus; Valves.—The supply of oxygen, or of other gas such as carbon dioxide or a mixture of oxygen and carbon dioxide, to airmen is regulated by a valve actuated by the atmospheric pressure so as to increase the supply as the pressure falls during an ascent. The apparatus comprises a chamber sealed by a diaphragm, and another chamber open to the atmosphere. The valve controlling the passage of gas from a reservoir through the outlet tube to a mask or mouthpiece is normally closed by a cam lever pivoted to a lever and formed with an arm held in position by a spring adjustable by means of a screw. Reduction of atmospheric pressure in the second chamber causes the diaphragm to move outwardly and so move the cam lever against the action of the spring and allow the passage of gas through the valve. Fall of pressure in the gas reservoir may be compensated for by pivoting the lever and fitting it with an adjustable screw bearing against an extension of a piston in communication with the gas reservoir through a valve. Fall of pressure in the reservoir allows the piston to be forced downwardly by a spring and so causes the lever to turn about its pivot and raises the cam lever and reduces its pressure on the valve. In modifications, the diaphragm may be replaced by a piston or bellows, the piston may be replaced by an expansible capsule or by bellows, and a secondary reservoir may be introduced between the valve and the facepiece, etc., and may be fitted with an outlet valve actuated by the atmospheric pressure or the same principle as the valve.

123,564. J. J. Morch, 5, Urswick Road, Hackney, London. February 21, 1918.

Aerial Machines without Aerostats; Propelling; Planes, Construction of.—An aeroplane is provided with a lifting-propeller at the tail, and may also have two other lifters arranged in openings in the main planes; or the lifters may be below, between, or above the planes.

Reference has been directed by the Comptroller to Specifications 29652/10 and 21625/12.

123,579. R. H. Davis, 187, Westminster Bridge Road, Westminster. February 26, 1918.

Breathing Apparatus.—A breathing mask for the use of aviators and others comprises a chamber covering the nose and mouth and formed of soft copper or other ductile material so that it may be made to conform closely to the face of the user. The chamber is mounted on a strip of soft leather, which may form a lining for the chamber and is fitted with an oxygen-inlet pipe and with air-inlet apertures, covered by ducts or louvers so as to prevent air from impinging directly on the face. The pipe may extend within the mask so as to enter the mouth, and in this case is perforated for the admission of air with the oxygen. In a modification, the louvers extend laterally on the mask.

123,585. H. R. Ricardo, 21, Suffolk Street, Pall Mall, London. February 27, 1918.

Internal Combustion Engines; Regulating.—The inlet valves of an engine for aircraft, etc., are each actuated by an adjustable cam controlled by a barometric device which acts upon a valve for regulating the supply and delivery of a liquid to and from a chamber containing a piston connected to mechanism for adjusting

the cam. Located between a pair of cams for actuating exhaust valves is an inlet valve cam, a portion of which may be adjusted angularly by a pin carried on a shaft. Rollers are secured to the end of the shaft and work in helical grooves formed in a sliding sleeve carried by a piston which reciprocates in a cylinder to which is supplied oil under pressure from a lubricating system. The cylinder communicates through ports, with a chamber in which slides an open-ended valve connected by a lever to a rod secured to a movable member of a barometric device. The lever is hinged to the piston and at its upper end it is adjustably connected to the rod. A movement of the rod in a left-hand direction places an oil-supply port in communication with one of the ports leading to the cylinder, admission of oil to which displaces the piston and so adjusts the cam as to reduce the period of opening of the inlet valve. This displacement of the piston alters the position of the fulcrum of the lever, thus moving the valve and closing this port. A movement of the rod in an opposite direction opens this port through which the oil from the cylinder is discharged into the interior of the valve. A manual actuation of the valve may be effected by a hand-lever which can adjust the cam to prolong but not reduce the opening of the inlet valve.

123,603. C. M. Poulsen, 36, Great Queen Street, Kingsway, London. March 5, 1918.

Planes, Arrangement of; Steering and Balancing.—In biplane or multiplane machines in which the planes may be collapsed together vertically to vary the effective surface, the adjustable planes are provided with centrally-arranged vertical frames capable of telescoping relatively to one another. The drawings show a triplane having a fixed middle plane and upper and lower adjustable planes, connected respectively to frames provided with racks engaging pinions operated through chain and worm or other gearing by the pilot. The interplane struts are replaced by cables arranged to be maintained in tension during the movements of the planes. Stay wires are connected to the frames. In the case of a biplane, the fixed plane is omitted.

Planes, Construction of.—The planes are shaped in cross sections so as to fit together when collapsed.

123,604. Priors Aerial Patents, Ltd., Imperial Buildings, Kingsway, London, and E. G. Prior 215, Upper Grosvenor Road, Tunbridge Wells, Kent. March 5, 1918.

Aerostats; Framework.—A keel for airships or the like is constructed of a series of laminated frames of veneer, duralumin, etc., so arranged relatively to each other that the stresses throughout the keel will be resisted equally in all directions. Each frame is made of quadrilateral form having two sides parallel but of unequal lengths, and the frames are alternately reversed with the inclined sides in contact and the parallel sides adjacent the longerons. The frames may be connected together and to the longerons by glueing or by a wrapping of veneers, metal, etc., with or without dowel pins, etc. The longerons may be laminated and may be arranged with the grain running toward the centre of the keel.

123,628. Cellon, Ltd., 22, Cork Street, and T. Tyrer and Co. and T. Tucker, Abbey Lane, Stratford, both in London. March 26, 1918.

Dopes, Varnishes, etc.—Dopes, varnishes, lacquers, etc., are formed by dissolving nitrocellulose in isobutyl isobutyrate, alone or together with other solvents such as acetone, butyl acetate, or other acetic acid esters.

H. T. P. Gee,
25, Victoria Street, Westminster, S.W.1, and
70, George Street, Croydon.

REVIEWS.

The Medical and Surgical Aspects of Aviation.

"The Medical and Surgical Aspects of Aviation," by H. Graeme Anderson, offers a highly interesting account of the medical work that has been carried out in connection with aviation during the war. One cannot perhaps give a better testimony to the book than by saying that had it appeared earlier it would have been of inestimable service to medical officers recruited for the Royal Air Force, and would have afforded them a sort of "vade mecum" in the performance of their duties.

The book commences with an historical survey of the part taken by the medical profession in the development of aviation before and during the war. Then follows a chapter on the selection of candidates for aviation, in which the disqualifying defects and the necessary physical and mental qualities for aviation are considered in some detail, and the methods and tests adopted by the medical service of the R.A.F. to examine for these are briefly described.

This is supplemented by a chapter on "The Applied Physiology of Aviation" by Colonel Flack, in which the special physical qualities essential to aviation and the tests applied for them are considered in more detail. There must be a rapid and nice co-ordination between the senses and the muscles and a sound cardio-respiratory apparatus to withstand the strain of high altitudes. The strain of high flying (15,000 to 20,000 feet) is due almost entirely to deficient supply of oxygen, and this can be largely compensated by inhalation of oxygen from cylinders of compressed gas or from liquid oxygen in a metal vacuum vaporiser. Extreme cold must also be provided against. Roughly the temperature falls 1° F. for every 365ft. From every point of view the aviator must keep himself fit and avoid excesses, especially in alcohol and tobacco.

Under the "Psychology of Aviation" the author does not enter into any abstruse psychological problems in relation to flying, but discusses in a very interesting manner such questions as the motives for taking up aviation, the subjective feelings of the first solo, including the author's own experience, and the mental strain involved in the various duties of a flying officer—fighting scout, bomber, instructor, etc.

The author refers to the work of the French on "reaction time" tests, by which aviators are examined for the interval of time between a visual, auditory or tactile sensation in the form of a signal and the muscular response. Any marked delay in response, which should be about one-fifth of a second, should disqualify the subject for aviation. He does not, however, mention the more recent work in America and in this country, which goes to show that such simple reaction time tests are of little value, being automatic, and that the psychological test of importance for aviation is one which measures the interval of time taken in the more conscious mental processes of discrimination and judgment such as are involved when there is a choice of two or more signals with corresponding different responses.

The term "aeroneuroses" is used to cover the various types of nervous breakdown that may arise in those engaged in flying. These are divided into two classes :—

(1) Those found among pupils.
(2) Those found among pilots engaged for the most part in war services.

(1) arises chiefly from (*a*) unsuitable temperament or (*b*) crashes.

When a pupil develops an aeroneurosis so as to lose confidence and all inclination to fly again it is of no avail to temporise with him. He should be discharged forthwith as unfit for flying. Experience has shown that there is little prospect of his ever making a good flying officer, and meanwhile there is a great risk of his infecting other pupils with the malady. The earlier a neurosis sets in, in a pupil's career, the more hopeless. On the other hand, if a pilot develops a neurosis after he has done 50-100 hours' flying it is always worth while to make an effort to save him for aviation. This is a sound principle and would undoubtedly be borne out by most medical officers with aviation experience.

The author very emphatically condemns the method that held sway at some training stations of sending a pupil up into the air forthwith after a crash, if he had not sustained any physical injury. He adds: "Bullying treatment with pupils never pays in a flying school." With the latter statement one heartily concurs, but for the rest the principle admits of some qualification. If the crash is due to the incompetence of an early soloist, the only proper course is to give further dual instruction, but if the crash is of a minor nature, occurs after some hours of successful solo flying and is due to some such mishap as engine failure, it has been found quite satisfactory to persuade the pupil to make another flight forthwith with perhaps the promise of a few days leave immediately afterwards. The second flight regains confidence, prevents brooding over the incidents of the crash and the pupil returns from his leave quite ready to continue his flying career.

The aeroneuroses of war flying are discussed by Dr. Gotch. He distinguishes six different types according to their causal origin and nature:—

(1) Those suffering from staleness, physical and mental, due to strain of service.
(2) Those in whom the breakdown is purely of mental origin from some unpleasant mental experience.
(3) Those suffering from some toxæmia.
(4) Those suffering from some physical defect, *i.e.*, ocular.
(5) Psychopaths.
(6) Malingerers.

Three flying accidents are especially adverse in relation to the prospect of recovery:—(1) Machine catching fire; (2) breakage in the air; (3) direct hit by anti-aircraft fire. Both Dr. Gotch and the author emphasise the importance of the past history, family history and flying record in estimating the possibility of recovery from an aeroneurosis, and above all the fact that the earlier the incidence of the trouble in the flying career, the less the chance of recovery.

Quite a considerable portion of the book is taken up with a chapter on flying accidents, very fully illustrated with plates, some of a very interesting nature, showing forced landings on such impossible places as the mast of a wireless station, treetops, telegraph wires and the side of Dover Castle.

One series of 58 accidents at a training station covering six months with 4,000 hours flying and 9,000 flights, bring out a number of interesting facts. The 58 accidents were attended with 16 injuries, equivalent to 28 injured in every 100 crashes and 1 pupil injured in every 560 flights. Analysis of the causes of the crashes showed that:—42 were due to error of judgment; 7 were due to loss of head; 4 were due to brain fatigue; 4 unavoidable; 1 due to aeroplane defect; so that 53 of the 58 were due to some mental deficiency on the part of the pupil. In this series there is "0" against "fear" as a cause of accident, presumably because none of the pupils admitted this, but it would appear difficult to distinguish this from "loss of head," or even "error of judgment." "Loss of head" means that the mental powers are temporarily paralysed and unable to direct and act properly, and such a mental paralysis is especially caused by the emotion of fear.

Similarly in a less degree fear may so far derange the intelligence as to cause error of judgment. It is a generally recognised fact that a large proportion of crashes occurring in early solos are due to "wind up."

In the chapter of the "Surgery of Aviation" further instructive details are given as to the special kinds of injury met with in aeroplane accidents, and a very full account of injuries to the feet, in particular fractures of the astragalus bone, peculiarly common in these accidents, illustrated with some excellent skiagrams.

As already stated the book should be of great value to medical officers of the Air Service, and to others of the profession interested in aviation. One might have wished that more space were devoted to a fuller consideration of some of the more technical medical problems, such as the sense of equilibration, reaction time tests, etc., but such omissions render the book all the more readable to non-medical flying enthusiasts, and it should find a wide circle of interested readers among them.

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